Geant4 v9.4

Geometry II

Joseph Perl (SLAC)
Presenting slides by Makoto Asai (SLAC)

Geant4 Tutorial Course

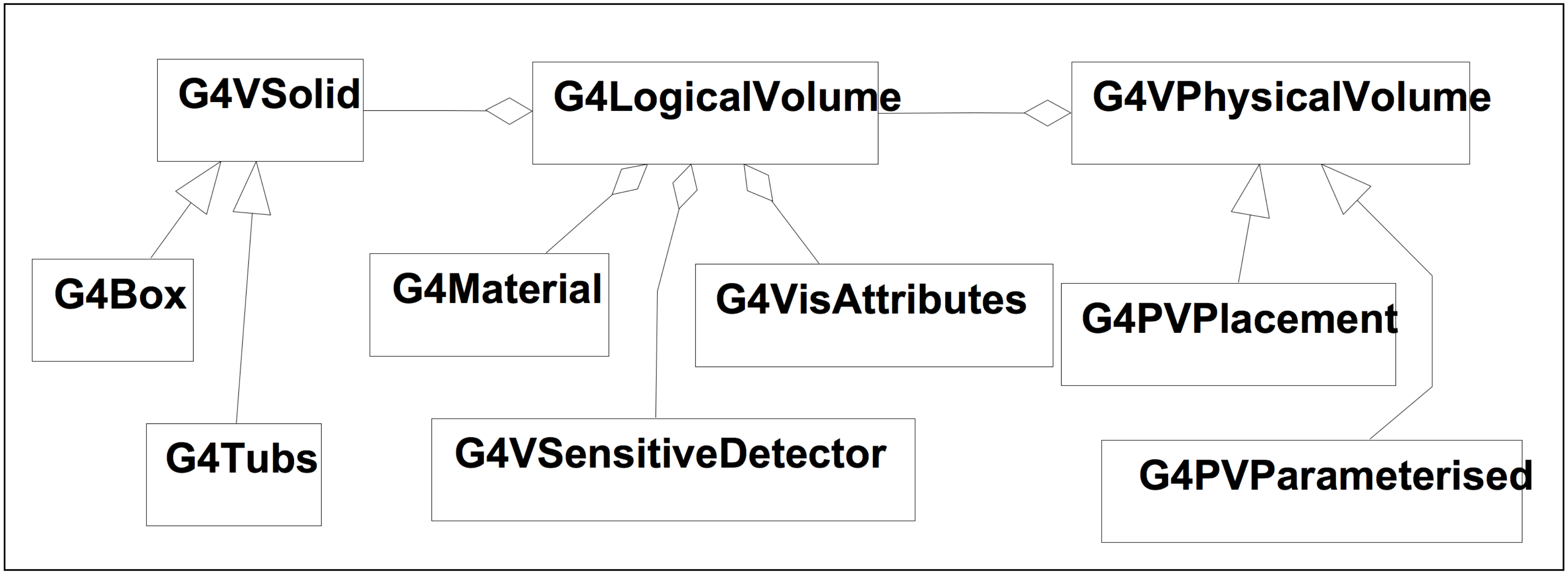
Contents

- Physical volume
- Placement
- Parameterized volume
- Replicated volume
- Divided volume
- Touchable

Physical volume

Detector geometry

- Three conceptual layers
  - G4VSolid -- *shape, size*
  - G4LogicalVolume -- *daughter physical volumes,*
    material, sensitivity, user limits, etc.
  - G4VPhysicalVolume -- *position, rotation*



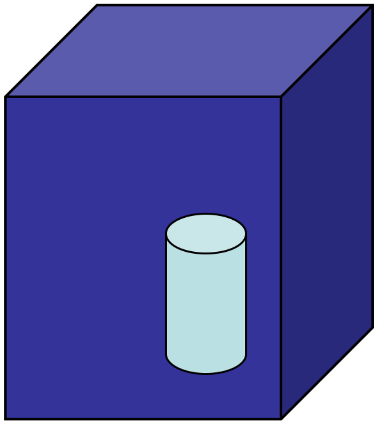
Define detector geometry

- Basic strategy

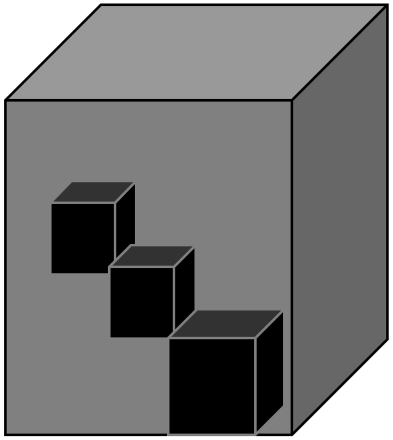
```
G4VSolid* pBoxSolid =
  new G4Box(“aBoxSolid”, 1.*m, 2.*m, 3.*m);
G4LogicalVolume* pBoxLog =
  new G4LogicalVolume( pBoxSolid, pBoxMaterial,
                        “aBoxLog”, 0, 0, 0);
G4VPhysicalVolume* aBoxPhys =
  new G4PVPlacement( pRotation,
    G4ThreeVector(posX, posY, posZ), pBoxLog,
    “aBoxPhys”, pMotherLog, 0, copyNo);
```

Physical Volumes

- Placement volume : it is one positioned volume
  - One physical volume object represents one “real” volume.
- Repeated volume : a volume placed many times
  - One physical volume object represents any number of “real” volumes.
  - reduces use of memory.
  - Parameterised
    - repetition w.r.t. copy number
  - Replica and Division
    - simple repetition along one axis
- A mother volume can contain either
  - many placement volumes
  - or, one repeated volume



placement



repeated

Physical volume

- G4PVPlacement 1 Placement = One Placement Volume
  - A volume instance positioned once in its mother volume
- G4PVParameterised 1 Parameterized = Many Repeated Volumes
  - Parameterized by the copy number
    - Shape, size, material, sensitivity, vis attributes, position and rotation can be parameterized by the copy number.
    - You have to implement a concrete class of G4VPVParameterisation.
  - Reduction of memory consumption
  - Currently: parameterization can be used only for volumes that either

    a) have no further daughters, or

    b) are identical in size & shape (so that grand-daughters are safely fit inside).
  - By implementing G4PVNestedParameterisation instead of G4VPVParameterisation, material, sensitivity and vis attributes can be parameterized by the copy numbers of ancestors.

Physical volume

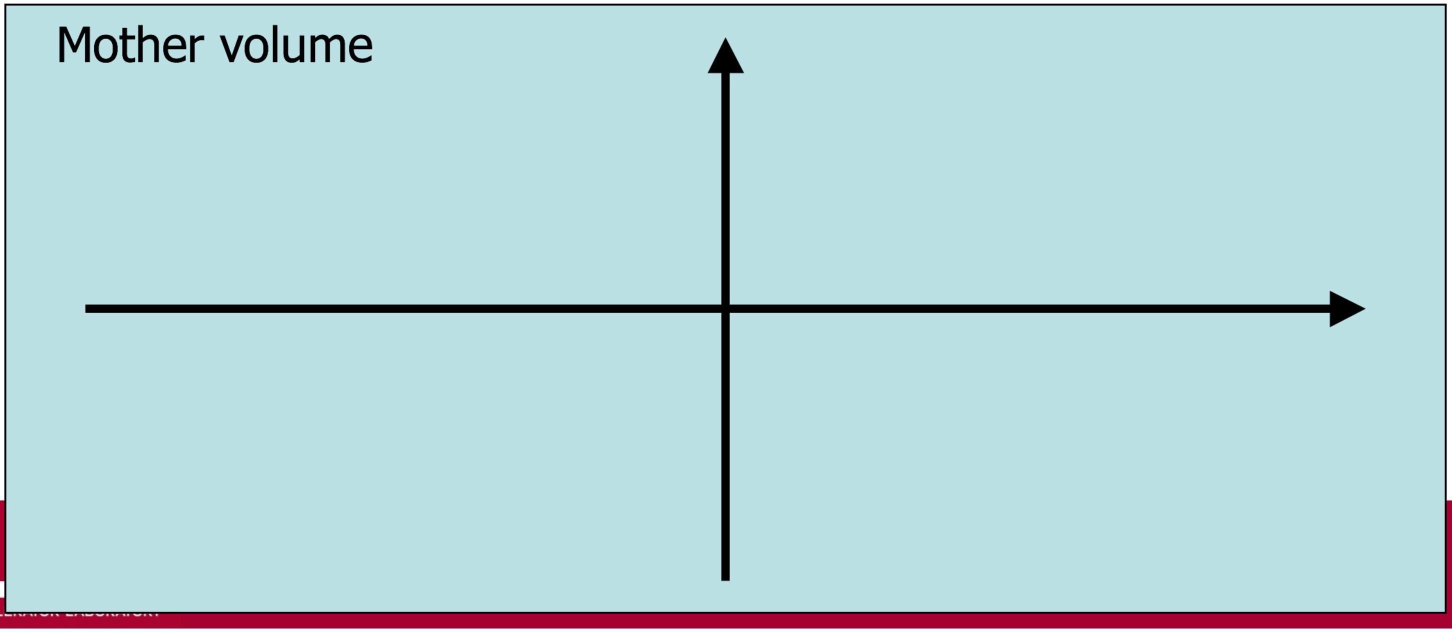
- G4PVReplica 1 Replica = Many Repeated Volumes
  - Daughters of same shape are aligned along one axis
  - Daughters fill the mother completely without gap in between.
- G4PVDivision 1 Division = Many Repeated Volumes
  - Daughters of same shape are aligned along one axis and fill the mother.
  - There can be gaps between mother wall and outmost daughters.
  - No gap in between daughters.
- G4ReflectionFactory 1 Placement = a pair of Placement volumes
  - generating placements of a volume and its reflected volume
  - Useful typically for end-cap calorimeter
- G4AssemblyVolume 1 Placement = a set of Placement volumes
  - Position a group of volumes

G4PVPlacement

G4PVPlacement

```
G4PVPlacement(
  G4Transform3D(G4RotationMatrix &pRot, // rotation of daughter volume
          const G4ThreeVector &tlate), // position in mother frame
  G4LogicalVolume *pDaughterLogical,
  const G4String &pName,
  G4LogicalVolume *pMotherLogical,
  G4bool pMany, // ‘true’ is not supported yet…
  G4int pCopyNo, // unique arbitrary integer
  G4bool pSurfChk=false); // optional boundary check
```

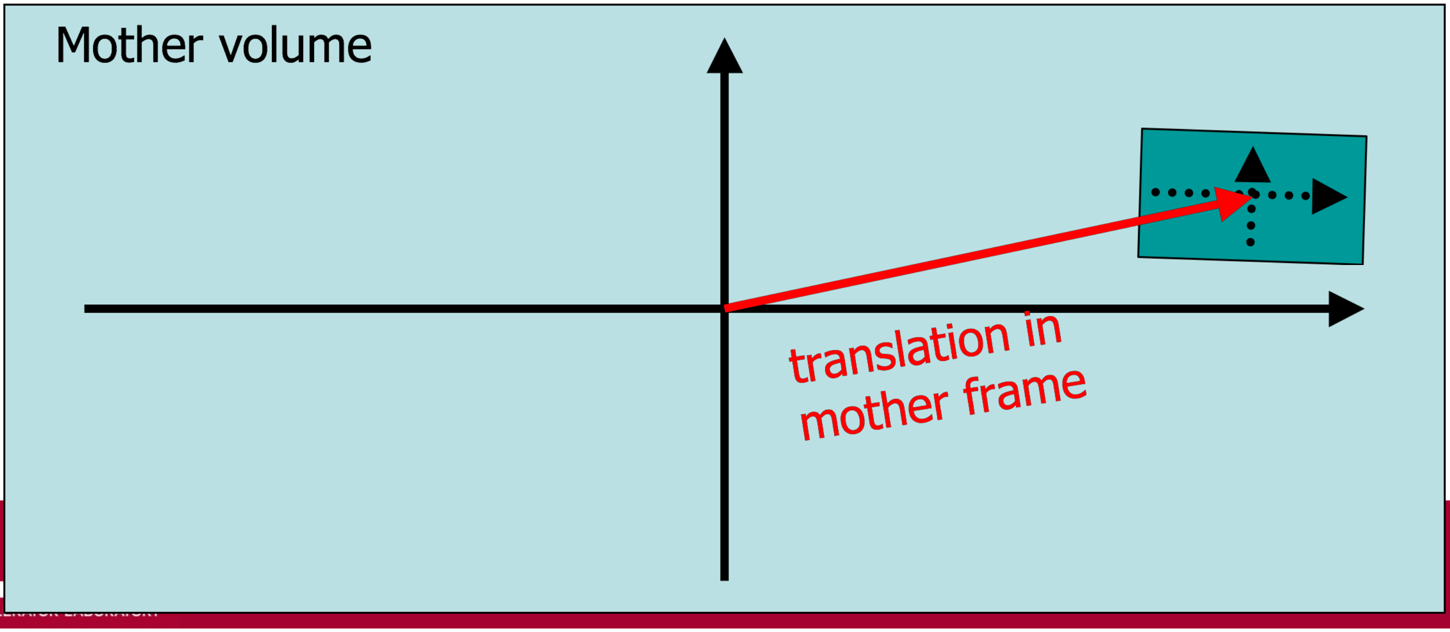
- Single volume positioned relatively to the mother volume.



G4PVPlacement

```
G4PVPlacement(
  G4Transform3D(G4RotationMatrix &pRot, // rotation of daughter volume
            const G4ThreeVector &tlate), // position in mother frame
  G4LogicalVolume *pDaughterLogical,
  const G4String &pName,
  G4LogicalVolume *pMotherLogical,
  G4bool pMany, // ‘true’ is not supported yet…
  G4int pCopyNo, // unique arbitrary integer
  G4bool pSurfChk=false); // optional boundary check
```

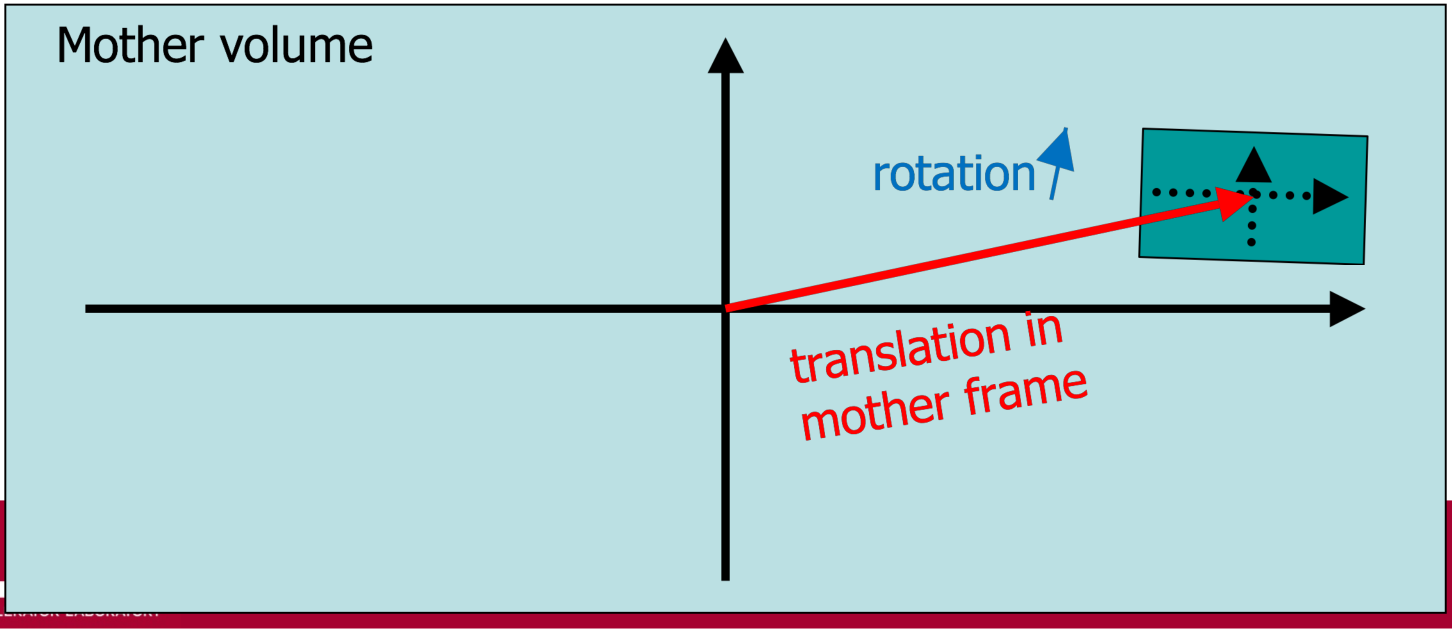
- Single volume positioned relatively to the mother volume.



G4PVPlacement

```
G4PVPlacement(
  G4Transform3D(G4RotationMatrix &pRot, // rotation of daughter volume
            const G4ThreeVector &tlate), // position in mother frame
  G4LogicalVolume *pDaughterLogical,
  const G4String &pName,
  G4LogicalVolume *pMotherLogical,
  G4bool pMany, // 'true' is not supported yet…
  G4int pCopyNo, // unique arbitrary integer
  G4bool pSurfChk=false); // optional boundary check
```

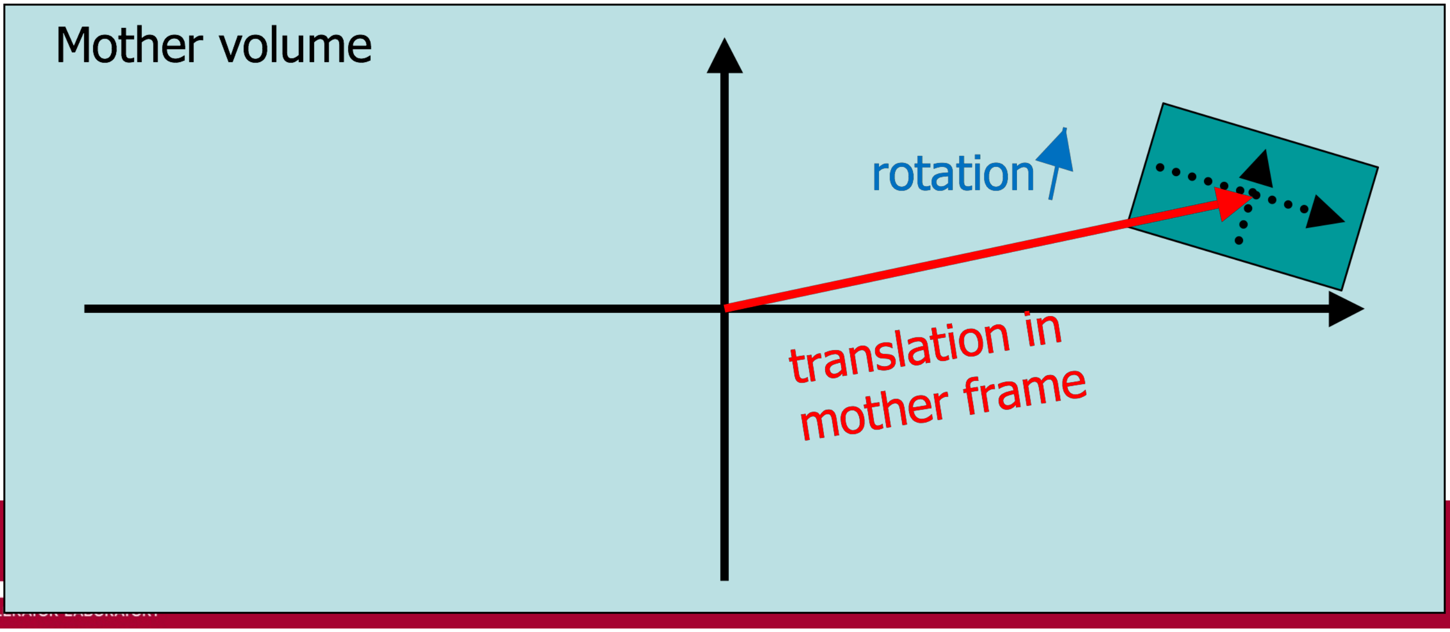
- Single volume positioned relatively to the mother volume.



G4PVPlacement

```
G4PVPlacement(
  G4Transform3D(G4RotationMatrix &pRot, // rotation of daughter volume
             const G4ThreeVector &tlate), // position in mother frame
  G4LogicalVolume *pDaughterLogical,
  const G4String &pName,
  G4LogicalVolume *pMotherLogical,
  G4bool pMany, // ‘true’ is not supported yet…
  G4int pCopyNo, // unique arbitrary integer
  G4bool pSurfChk=false); // optional boundary check
```

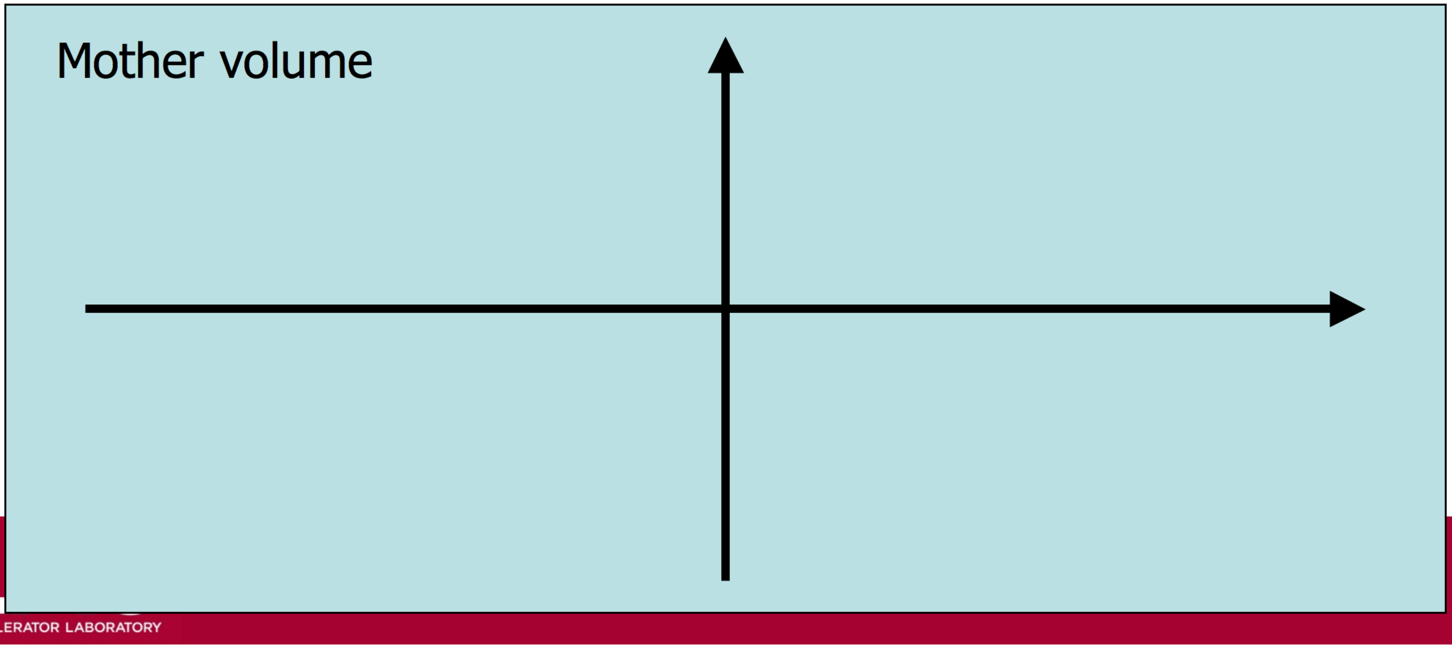
- Single volume positioned relatively to the mother volume.



Alternative G4PVPlacement

```
G4PVPlacement(G4RotationMatrix* pRot,   // rotation of mother frame
            const G4ThreeVector &tlate, // position in mother frame
            G4LogicalVolume *pDaughterLogical,
            const G4String &pName,
            G4LogicalVolume *pMotherLogical,
            G4bool pMany, // ‘true’ is not supported yet…
            G4int pCopyNo, // unique arbitrary integer
            G4bool pSurfChk=false); // optional boundary check
```

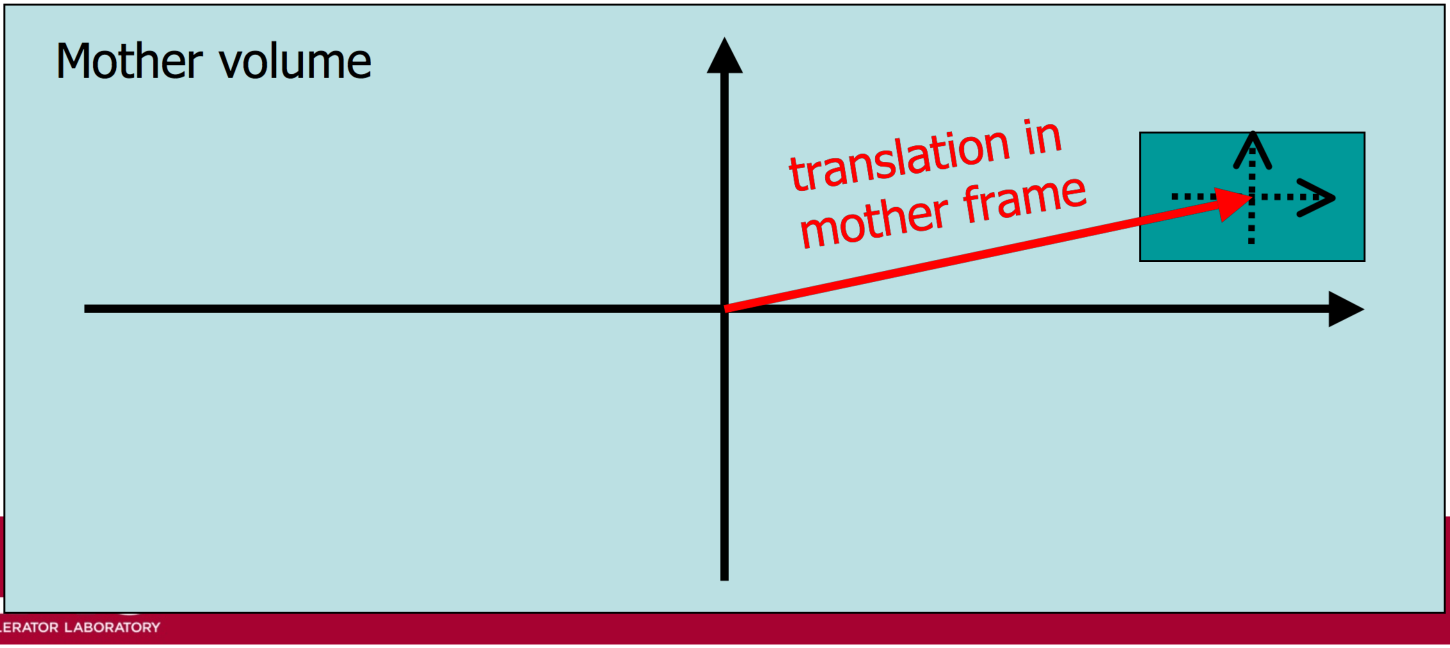
- Single volume positioned relatively to the mother volume.



Alternative G4PVPlacement

```
G4PVPlacement(G4RotationMatrix* pRot,   // rotation of mother frame
              const G4ThreeVector &tlate, // position in mother frame
              G4LogicalVolume *pDaughterLogical,
              const G4String &pName,
              G4LogicalVolume *pMotherLogical,
              G4bool pMany, // ‘true’ is not supported yet…
              G4int pCopyNo, // unique arbitrary integer
              G4bool pSurfChk=false); // optional boundary check
```

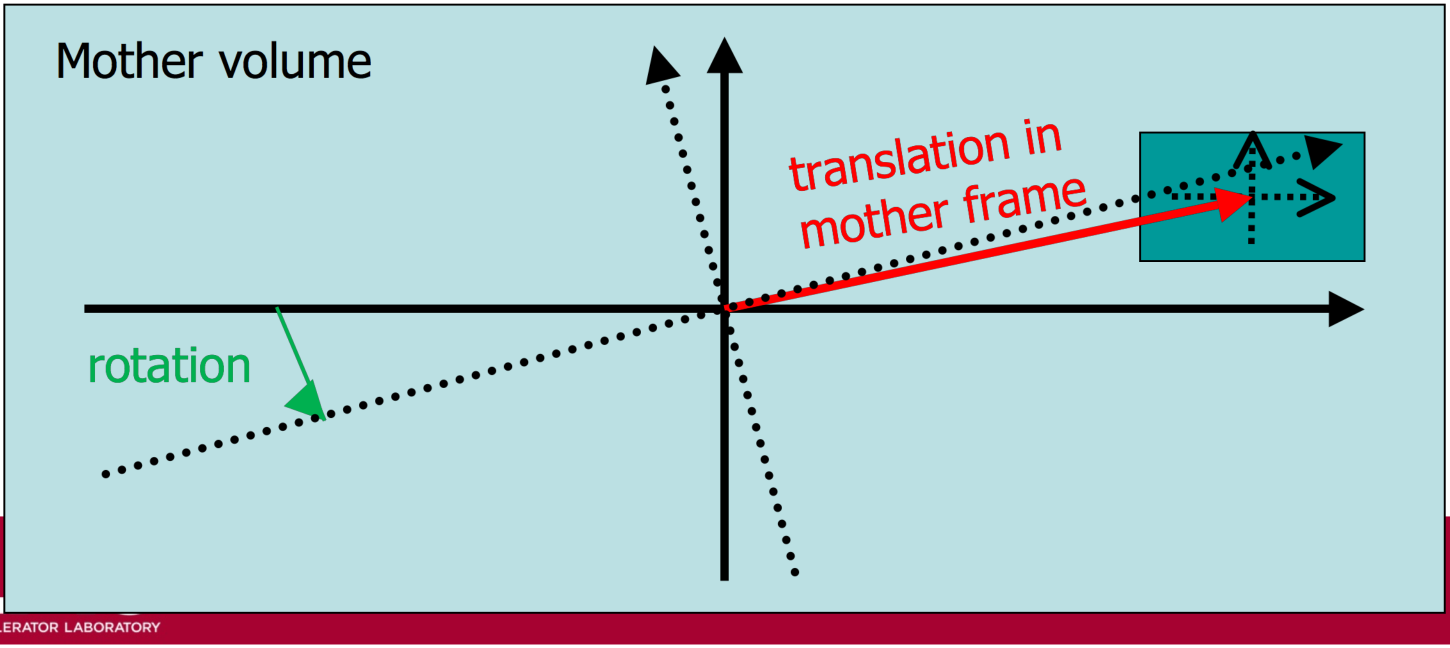
- Single volume positioned relatively to the mother volume.



Alternative G4PVPlacement

```
G4PVPlacement(G4RotationMatrix* pRot,   // rotation of mother frame
            const G4ThreeVector &tlate, // position in mother frame
            G4LogicalVolume *pDaughterLogical,
            const G4String &pName,
            G4LogicalVolume *pMotherLogical,
            G4bool pMany, // ‘true’ is not supported yet…
            G4int pCopyNo, // unique arbitrary integer
            G4bool pSurfChk=false); // optional boundary check
```

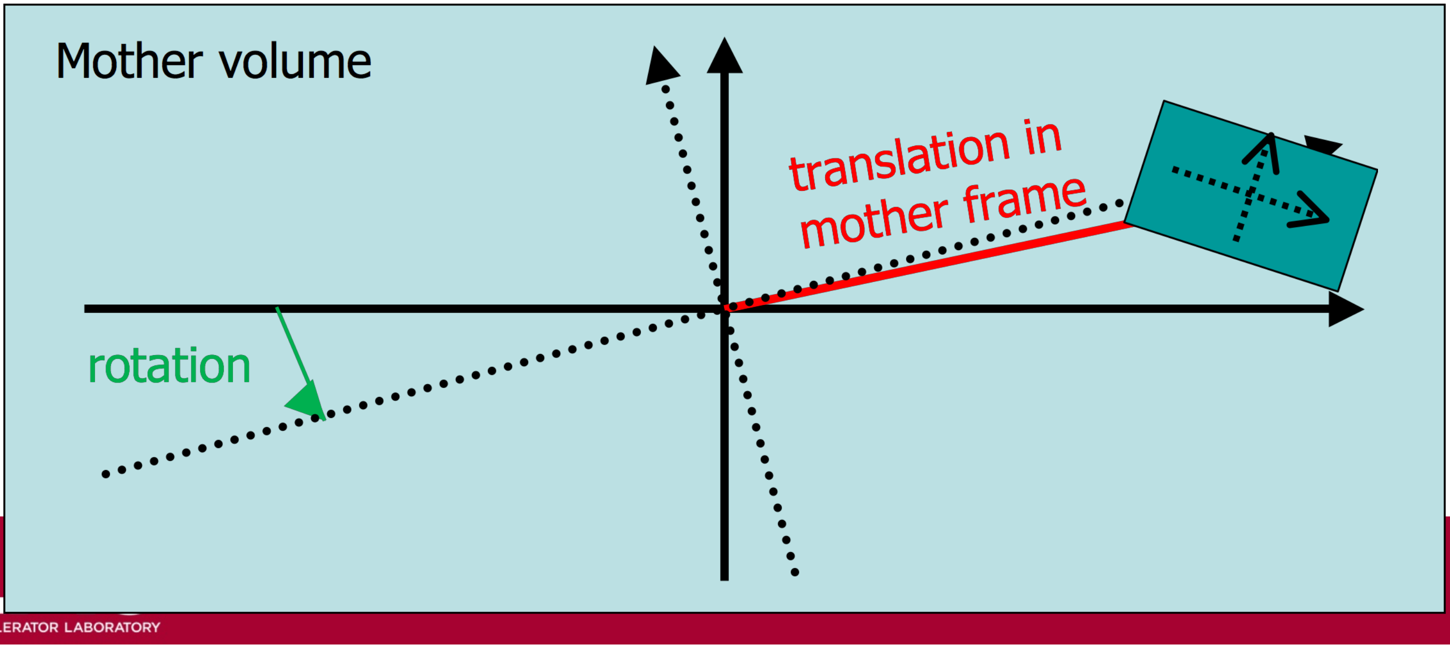
- Single volume positioned relatively to the mother volume.



Alternative G4PVPlacement

```
G4PVPlacement(G4RotationMatrix* pRot,   // rotation of mother frame
              const G4ThreeVector &tlate, // position in mother frame
              G4LogicalVolume *pDaughterLogical,
              const G4String &pName,
              G4LogicalVolume *pMotherLogical,
              G4bool pMany, // 'true' is not supported yet…
              G4int pCopyNo, // unique arbitrary integer
              G4bool pSurfChk=false); // optional boundary check
```

- Single volume positioned relatively to the mother volume.



Alternative G4PVPlacement

```
G4PVPlacement(G4RotationMatrix* pRot,   // rotation of mother frame
              const G4ThreeVector &tlate, // position in mother frame
              G4LogicalVolume *pDaughterLogical,
              const G4String &pName,
              G4LogicalVolume *pMotherLogical,
              G4bool pMany, // ‘true’ is not supported yet…
```

Note:

- This G4PVPlacement is identical to the previous one if there is no rotation.
  - Previous one is much easier to understand.
- The advantage of this second constructor is setting the pointer of the rotation matrix rather than providing the values of the matrix.
  - You may change the matrix without accessing to the physical volume.
  - This is for power-users, though.

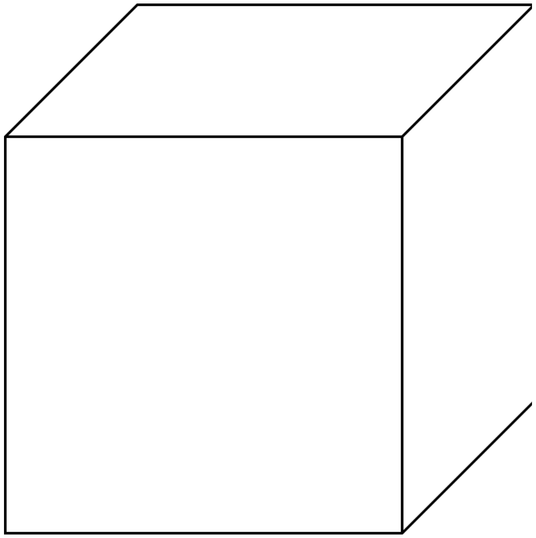
Parameterized volume

G4PVParameterised

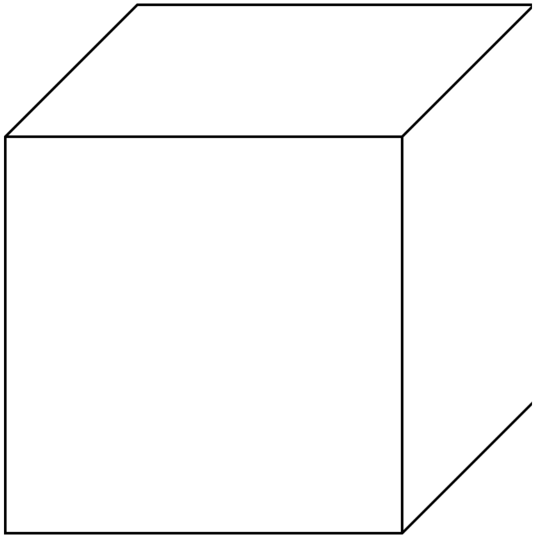
```
G4PVParameterised(const G4String& pName,
                  G4LogicalVolume* pLogical,
                  G4LogicalVolume* pMother,
                  const EAxis pAxis,
                  const G4int nReplicas,
                  G4VPVParameterisation* pParam
                  G4bool pSurfChk=false);
```

- Replicates the volume **nReplicas** times using the parameterization **pParam**, within the mother volume **pMother**
- **pAxis** is a "suggestion" to the navigator along which Cartesian axis replication of parameterized volumes dominates.
  - kXAxis, kYAxis, kZAxis : one-dimensional optimization
  - kUndefined : three-dimensional optimization

Parameterized Physical Volumes

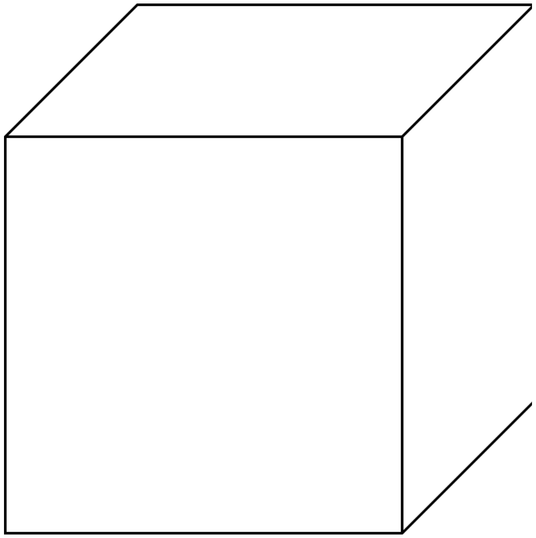


Parameterized Physical Volumes



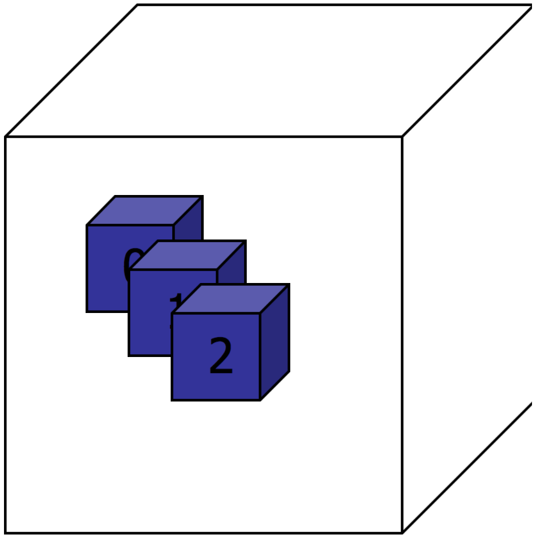
Parameterized Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define following as a function of copy number
  - where it is positioned (transformation, rotation)



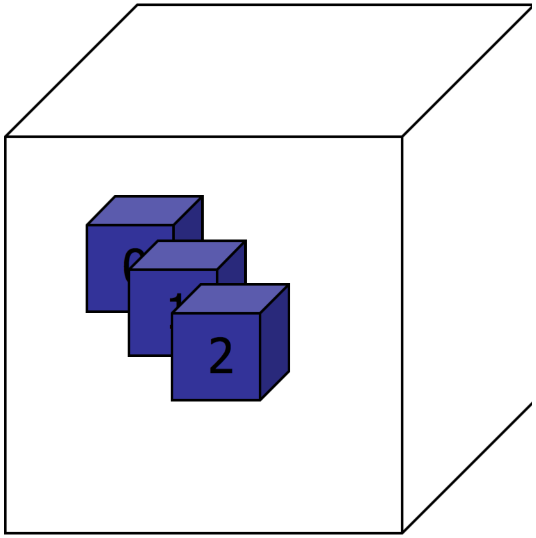
Parameterized Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define following as a function of copy number
  - where it is positioned (transformation, rotation)



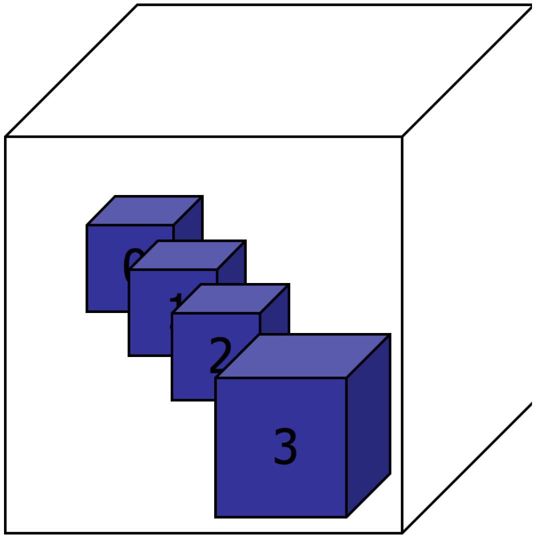
Parameterized Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define following as a function of copy number
  - where it is positioned (transformation, rotation)
- Optional:
  - the size of the solid (dimensions)



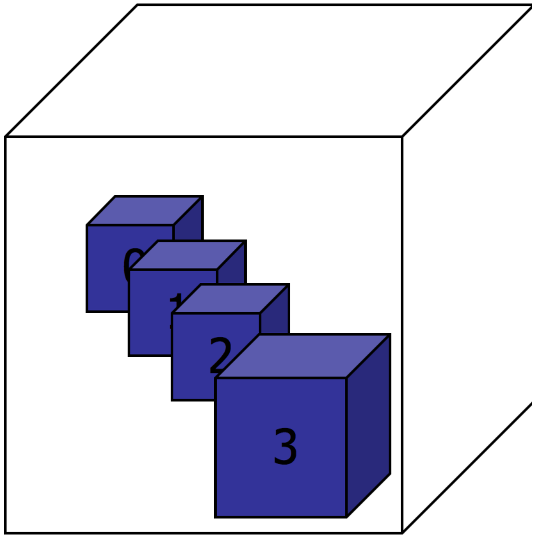
Parameterized Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define following as a function of copy number
  - where it is positioned (transformation, rotation)
- Optional:
  - the size of the solid (dimensions)



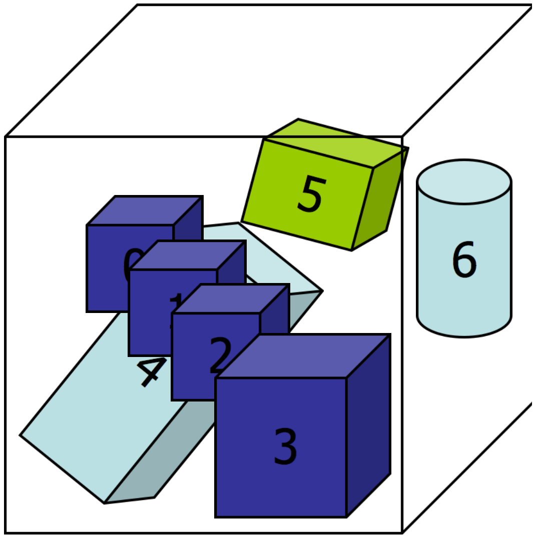
Parameterized Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define following as a function of copy number
  - where it is positioned (transformation, rotation)
- Optional:
  - the size of the solid (dimensions)
  - the type of the solid, material, sensitivity, vis attributes



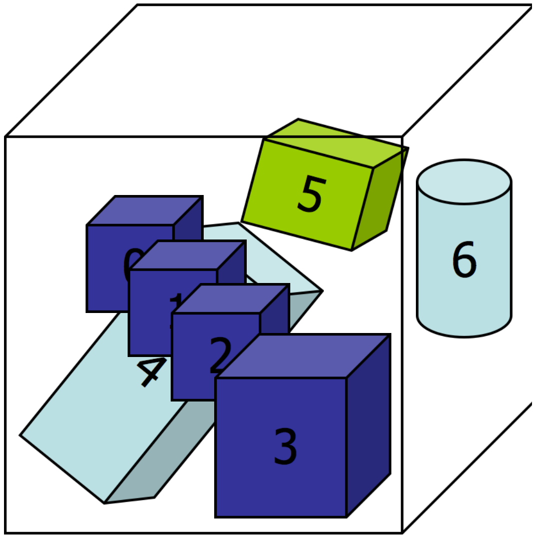
Parameterized Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define following as a function of copy number
  - where it is positioned (transformation, rotation)
- Optional:
  - the size of the solid (dimensions)
  - the type of the solid, material, sensitivity, vis attributes



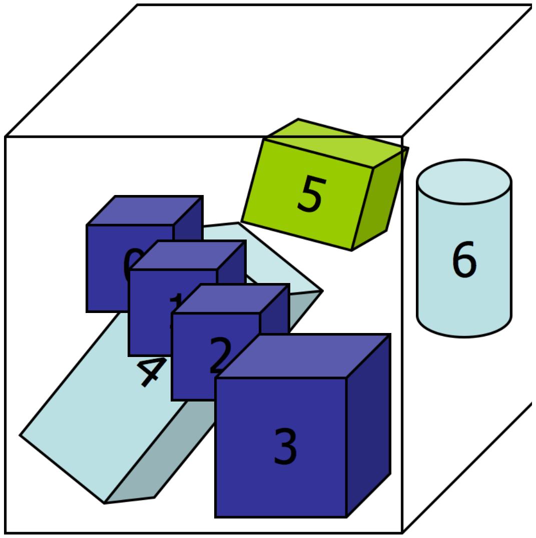
Parameterized Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define following as a function of copy number
  - where it is positioned (transformation, rotation)
- Optional:
  - the size of the solid (dimensions)
  - the type of the solid, material, sensitivity, vis attributes
- All daughters must be fully contained in the mother.
- Daughters should not overlap to each other.



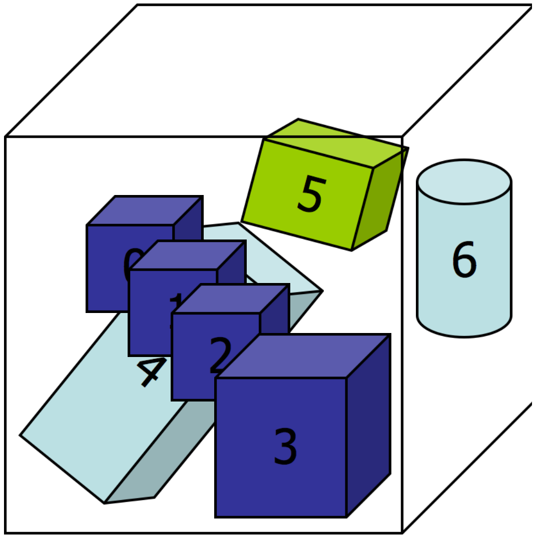
Parameterized Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define following as a function of copy number
  - where it is positioned (transformation, rotation)
- Optional:
  - the size of the solid (dimensions)
  - the type of the solid, material, sensitivity, vis attributes
- All daughters must be fully contained in the mother.
- Daughters should not overlap to each other.
- Limitations:
  - Applies to simple CSG solids only
  - Granddaughter volumes allowed only for special cases
  - Consider parameterised volumes as "leaf" volumes



Parameterized Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define following as a function of copy number
  - where it is positioned (transformation, rotation)
- Optional:
  - the size of the solid (dimensions)
  - the type of the solid, material, sensitivity, vis attributes
- All daughters must be fully contained in the mother.
- Daughters should not overlap to each other.
- Limitations:
  - Applies to simple CSG solids only
  - Granddaughter volumes allowed only for special cases
  - Consider parameterised volumes as “leaf” volumes
- Typical use-cases
  - Complex detectors
    - with large repetition of volumes, regular or irregular
  - Medical applications
    - the material in animal tissue is measured as cubes with varying material



G4PVParameterized : example

```
G4VSolid* solidChamber =
   new G4Box("chamber", 100*cm, 100*cm, 10*cm);
G4LogicalVolume* logicChamber =
   new G4LogicalVolume
   (solidChamber, ChamberMater, "Chamber", 0, 0, 0);
G4VPVParameterisation* chamberParam =
   new ChamberParameterisation();
G4VPhysicalVolume* physChamber =
   new G4PVParameterised("Chamber", logicChamber,
        logicMother, kZAxis, NbOfChambers, chamberParam);
```

G4VPVParameterisation : example

```
class ChamberParameterisation : public G4VPVParameterisation
{
  public:
   ChamberParameterisation();
   virtual ~ChamberParameterisation();
   virtual void ComputeTransformation // position, rotation
     (const G4int copyNo, G4VPhysicalVolume* physVol) const;
   virtual void ComputeDimensions // size
     (G4Box& trackerLayer, const G4int copyNo,
         const G4VPhysicalVolume* physVol) const;
   virtual G4VSolid* ComputeSolid // shape
     (const G4int copyNo, G4VPhysicalVolume* physVol);
   virtual G4Material* ComputeMaterial // material, sensitivity, visAtt
     (const G4int copyNo, G4VPhysicalVolume* physVol,
         const G4VTouchable *parentTouch=0);
       // G4VTouchable should not be used for ordinary parameterization
};
```

G4VPVParameterisation : example

```
void ChamberParameterisation::ComputeTransformation
(const G4int copyNo, G4VPhysicalVolume* physVol) const
{
  G4double Xposition = … // w.r.t. copyNo
  G4ThreeVector origin(Xposition,Yposition,Zposition);
  physVol->SetTranslation(origin);
  physVol->SetRotation(0);
}

void ChamberParameterisation::ComputeDimensions
(G4Box& trackerChamber, const G4int copyNo,
 const G4VPhysicalVolume* physVol) const
{
  G4double XhalfLength = … // w.r.t. copyNo
  trackerChamber.SetXHalfLength(XhalfLength);
  trackerChamber.SetYHalfLength(YhalfLength);
  trackerChamber.SetZHalfLength(ZHalfLength);
}
```

G4VPVParameterisation : example

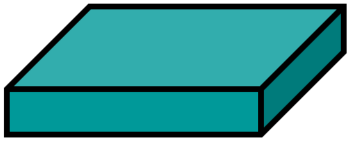
```
G4VSolid* ChamberParameterisation::ComputeSolid
     (const G4int copyNo, G4VPhysicalVolume* physVol)
{
  G4VSolid* solid;
  if(copyNo == …) solid = myBox;
  else if(copyNo == …) solid = myTubs;
  …
  return solid;
}

G4Material* ComputeMaterial // material, sensitivity, visAtt
     (const G4int copyNo, G4VPhysicalVolume* physVol,
         const G4VTouchable *parentTouch=0);
{
  G4Material* mat;
  if(copyNo == …)
  {
    mat = material1;
    physVol->GetLogicalVolume()->SetVisAttributes( att1 );
  }
  …
  return mat;
}
```

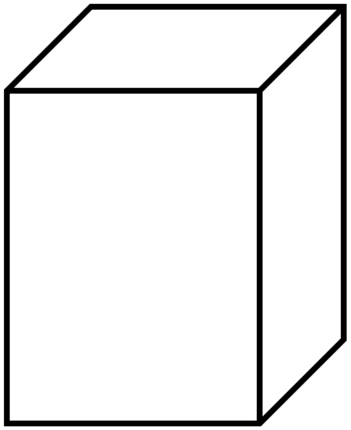
Replicated volume

Replicated Volumes

- The mother volume is completely filled with replicas, all of which are the same size (width) and shape.
- Replication may occur along:
  - Cartesian axes (X, Y, Z) – slices are considered perpendicular to the axis of replication
    - Coordinate system at the center of each replica
  - Radial axis (Rho) – cons/tubs sections centered on the origin and un-rotated
    - Coordinate system same as the mother
  - Phi axis (Phi) – phi sections or wedges, of cons/tubs form
    - Coordinate system rotated such as that the X axis bisects the angle made by each wedge



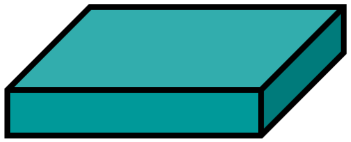
a daughter logical volume to be replicated



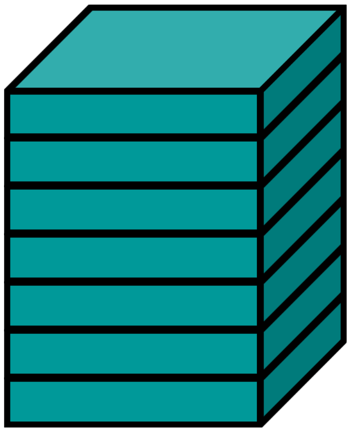
mother volume

Replicated Volumes

- The mother volume is completely filled with replicas, all of which are the same size (width) and shape.
- Replication may occur along:
  - Cartesian axes (X, Y, Z) – slices are considered perpendicular to the axis of replication
    - Coordinate system at the center of each replica
  - Radial axis (Rho) – cons/tubs sections centered on the origin and un-rotated
    - Coordinate system same as the mother
  - Phi axis (Phi) – phi sections or wedges, of cons/tubs form
    - Coordinate system rotated such as that the X axis bisects the angle made by each wedge



a daughter logical volume to be replicated



mother volume

G4PVReplica

```
G4PVReplica(const G4String &pName,
            G4LogicalVolume *pLogical,
            G4LogicalVolume *pMother,
            const EAxis pAxis,
            const G4int nReplicas,
            const G4double width,
            const G4double offset=0.);
```

- `offset` may be used only for tube/cone segment
- Features and restrictions:
  - Replicas can be placed inside other replicas
  - Normal placement volumes can be placed inside replicas, assuming no intersection/overlaps with the mother volume or with other replicas
  - No volume can be placed inside a radial replication
  - Parameterised volumes cannot be placed inside a replica

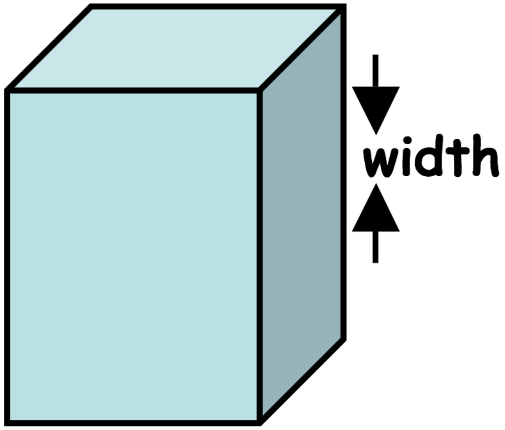
Replica - axis, width, offset

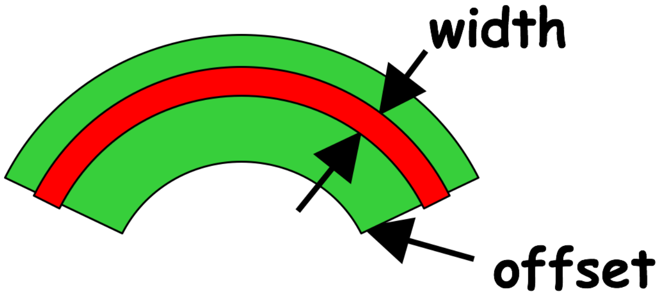
- Cartesian axes - **`kXaxis, kYaxis, kZaxis`**
  - Center of n-th daughter is given as

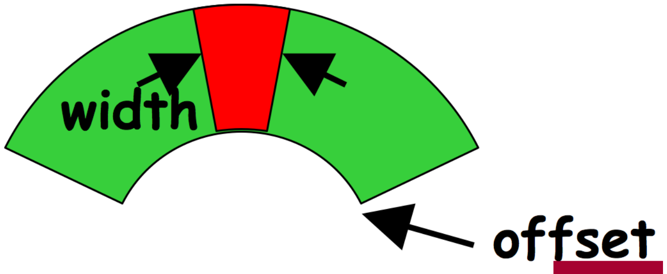
    `-width*(nReplicas-1)*0.5+n*width`
  - Offset shall not be used
- Radial axis - **`kRaxis`**
  - Center of n-th daughter is given as

    `width*(n+0.5)+offset`
  - Offset must be the inner radius of the mother
- Phi axis - **`kPhi`**
  - Center of n-th daughter is given as

    `width*(n+0.5)+offset`
  - Offset must be the starting angle of the mother







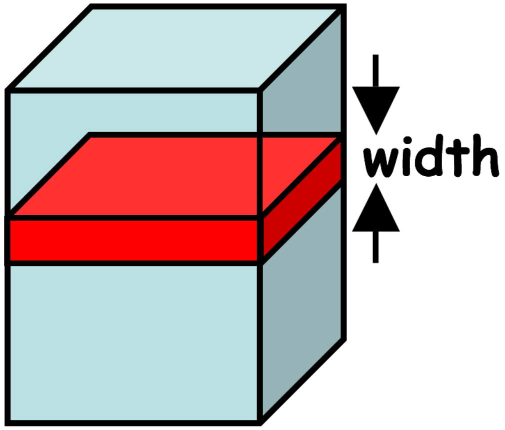
Replica - axis, width, offset

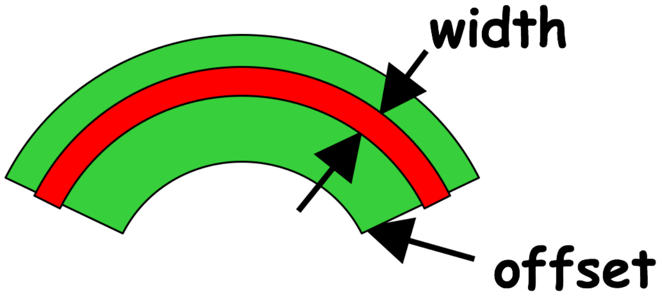
- Cartesian axes - **`kXaxis, kYaxis, kZaxis`**
  - Center of n-th daughter is given as

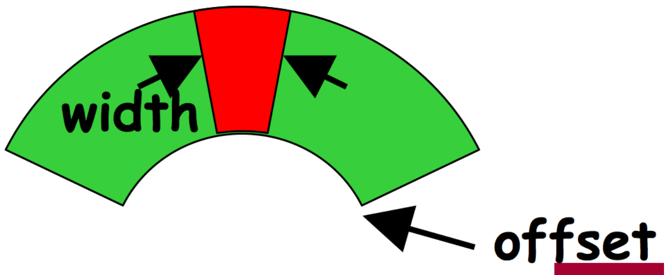
    `-width*(nReplicas-1)*0.5+n*width`
  - Offset shall not be used
- Radial axis - **`kRaxis`**
  - Center of n-th daughter is given as

    `width*(n+0.5)+offset`
  - Offset must be the inner radius of the mother
- Phi axis - **`kPhi`**
  - Center of n-th daughter is given as

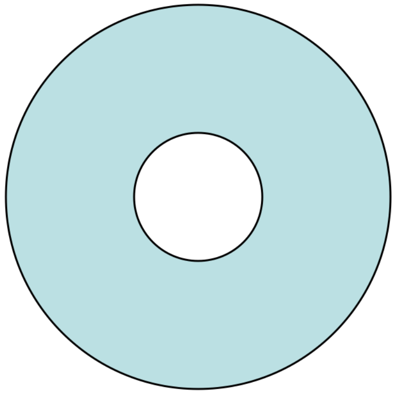
    `width*(n+0.5)+offset`
  - Offset must be the starting angle of the mother



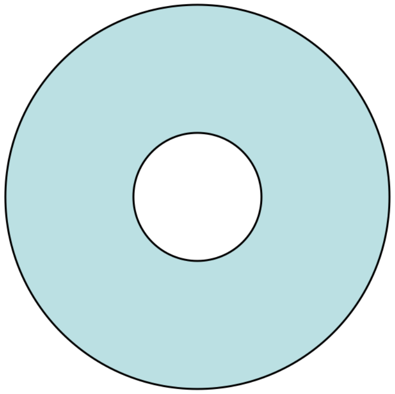




G4PVReplica : example

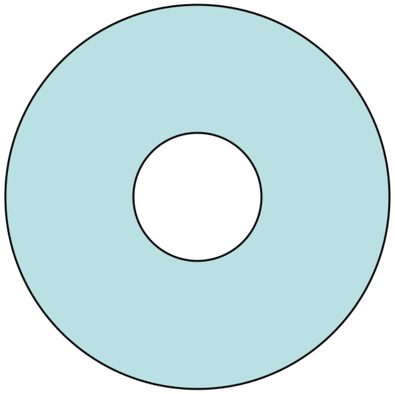


G4PVReplica : example



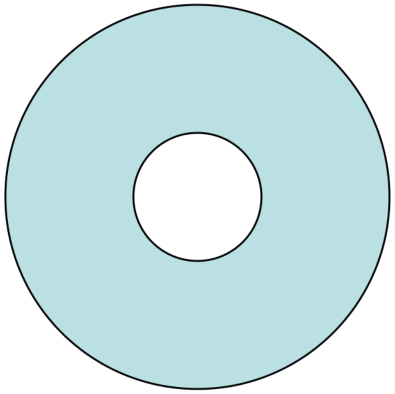
G4PVReplica : example

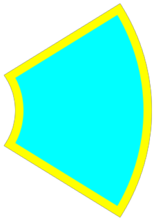
```
G4double tube_dPhi = 2.* M_PI * rad;
G4VSolid* tube =
   new G4Tubs("tube",20*cm,50*cm,30*cm,0.,tube_dPhi);
G4LogicalVolume * tube_log =
   new G4LogicalVolume(tube, Air, "tubeL", 0, 0, 0);
G4VPhysicalVolume* tube_phys =
   new G4PVPlacement(0,G4ThreeVector(-200.*cm,0.,0.),
            "tubeP", tube_log, world_phys, false, 0);
```



G4PVReplica : example

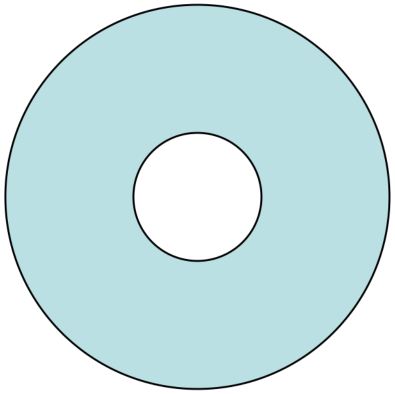
```
G4double tube_dPhi = 2.* M_PI * rad;
G4VSolid* tube =
   new G4Tubs("tube",20*cm,50*cm,30*cm,0.,tube_dPhi);
G4LogicalVolume * tube_log =
   new G4LogicalVolume(tube, Air, "tubeL", 0, 0, 0);
G4VPhysicalVolume* tube_phys =
   new G4PVPlacement(0,G4ThreeVector(-200.*cm,0.,0.),
            "tubeP", tube_log, world_phys, false, 0);
G4double divided_tube_dPhi = tube_dPhi/6.;
G4VSolid* div_tube =
   new G4Tubs("div_tube", 20*cm, 50*cm, 30*cm,
        -divided_tube_dPhi/2., divided_tube_dPhi);
G4LogicalVolume* div_tube_log =
   new G4LogicalVolume(div_tube,Pb,"div_tubeL",0,0,0);
```

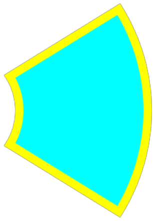




G4PVReplica : example

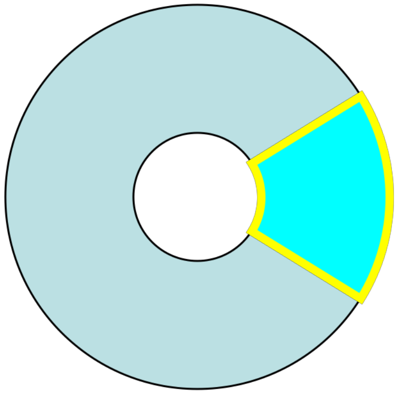
```
G4double tube_dPhi = 2.* M_PI * rad;
G4VSolid* tube =
   new G4Tubs("tube",20*cm,50*cm,30*cm,0.,tube_dPhi);
G4LogicalVolume * tube_log =
   new G4LogicalVolume(tube, Air, "tubeL", 0, 0, 0);
G4VPhysicalVolume* tube_phys =
   new G4PVPlacement(0,G4ThreeVector(-200.*cm,0.,0.),
            "tubeP", tube_log, world_phys, false, 0);
G4double divided_tube_dPhi = tube_dPhi/6.;
G4VSolid* div_tube =
   new G4Tubs("div_tube", 20*cm, 50*cm, 30*cm,
        -divided_tube_dPhi/2., divided_tube_dPhi);
G4LogicalVolume* div_tube_log =
   new G4LogicalVolume(div_tube,Pb,"div_tubeL",0,0,0);
G4VPhysicalVolume* div_tube_phys =
   new G4PVReplica("div_tube_phys", div_tube_log,
   tube_log, kPhi, 6, divided_tube_dPhi);
```





G4PVReplica : example

```
G4double tube_dPhi = 2.* M_PI * rad;
G4VSolid* tube =
   new G4Tubs("tube",20*cm,50*cm,30*cm,0.,tube_dPhi);
G4LogicalVolume * tube_log =
   new G4LogicalVolume(tube, Air, "tubeL", 0, 0, 0);
G4VPhysicalVolume* tube_phys =
   new G4PVPlacement(0,G4ThreeVector(-200.*cm,0.,0.),
            "tubeP", tube_log, world_phys, false, 0);
G4double divided_tube_dPhi = tube_dPhi/6.;
G4VSolid* div_tube =
   new G4Tubs("div_tube", 20*cm, 50*cm, 30*cm,
        -divided_tube_dPhi/2., divided_tube_dPhi);
G4LogicalVolume* div_tube_log =
   new G4LogicalVolume(div_tube,Pb,"div_tubeL",0,0,0);
G4VPhysicalVolume* div_tube_phys =
   new G4PVReplica("div_tube_phys", div_tube_log,
   tube_log, kPhi, 6, divided_tube_dPhi);
```



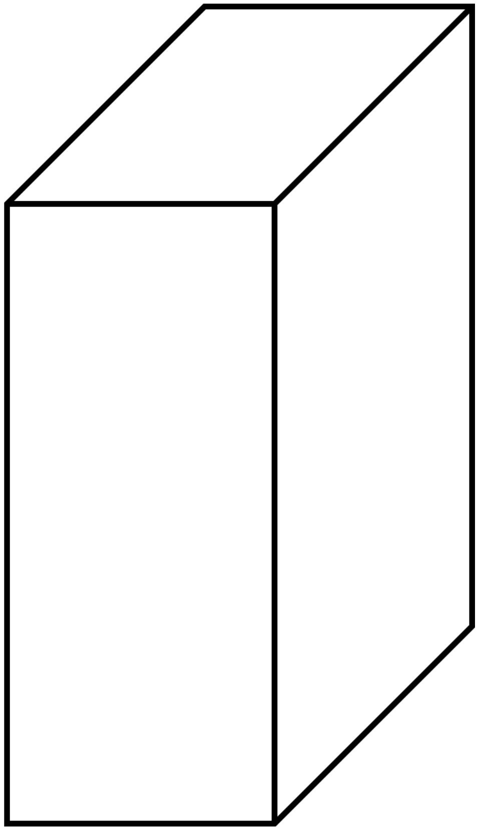
NATIONAL ACCELERATOR LABORATORY

Divided volume

Geant 4

G4PVDivision

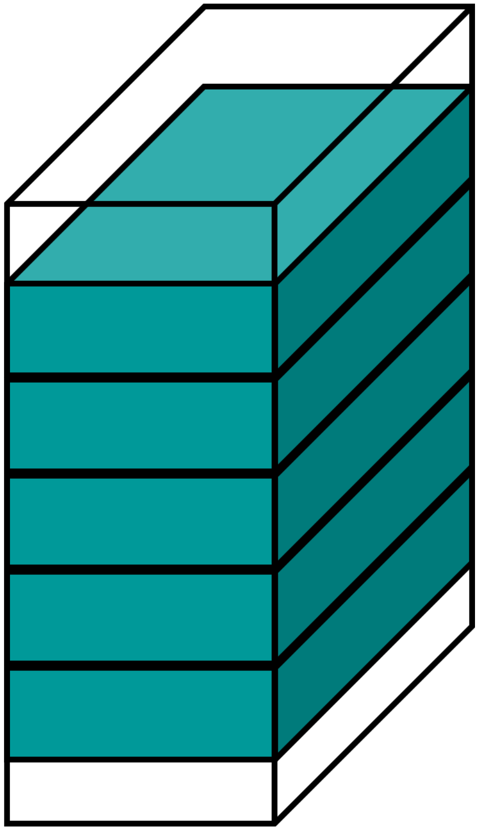
- G4PVDivision is a special kind of G4PVParameterised.
  - G4VPVParameterisation is automatically generated according to the parameters given in G4PVDivision.
- G4PVDivision is similar to G4PVReplica but
  - It currently allows gaps in between mother and daughter volumes
  - We are extending G4PVDivision to allow gaps between daughters, and also gaps on side walls. We plan to release this extension in near future.
- Shape of all daughter volumes must be same shape as the mother volume.
  - G4VSolid (to be assigned to the daughter logical volume) must be the same type, but different object.
- Replication must be aligned along one axis.
- If your geometry does not have gaps, use G4Replica.
  - For identical geometry, navigation of G4Replica is faster.



mother volume

G4PVDivision

- G4PVDivision is a special kind of G4PVParameterised.
  - G4VPVParameterisation is automatically generated according to the parameters given in G4PVDivision.
- G4PVDivision is similar to G4PVReplica but
  - It currently allows gaps in between mother and daughter volumes
  - We are extending G4PVDivision to allow gaps between daughters, and also gaps on side walls. We plan to release this extension in near future.
- Shape of all daughter volumes must be same shape as the mother volume.
  - G4VSolid (to be assigned to the daughter logical volume) must be the same type, but different object.
- Replication must be aligned along one axis.
- If your geometry does not have gaps, use G4Replica.
  - For identical geometry, navigation of G4Replica is faster.

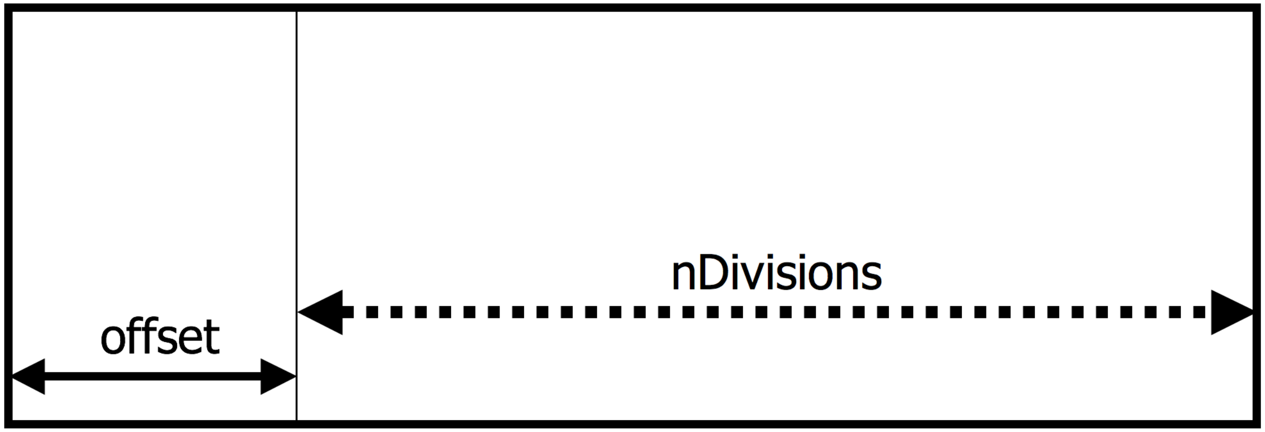


mother volume

G4PVDivision - 1

```
G4PVDivision(const G4String& pName,
    G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,
    const EAxis pAxis,
    const G4int nDivisions,    // number of division is given
    const G4double offset);
```

- The size (width) of the daughter volume is calculated as
  `( (size of mother) - offset ) / nDivisions`

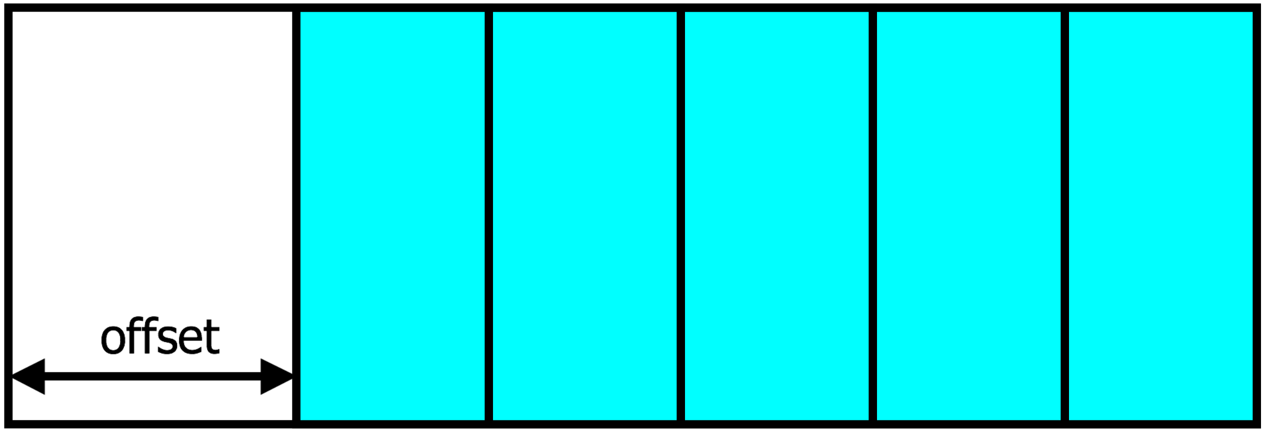


G4PVDivision - 1

```
G4PVDivision(const G4String& pName,
    G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,
    const EAxis pAxis,
    const G4int nDivisions,    // number of division is given
    const G4double offset);
```

- The size (width) of the daughter volume is calculated as

  `( (size of mother) - offset ) / nDivisions`



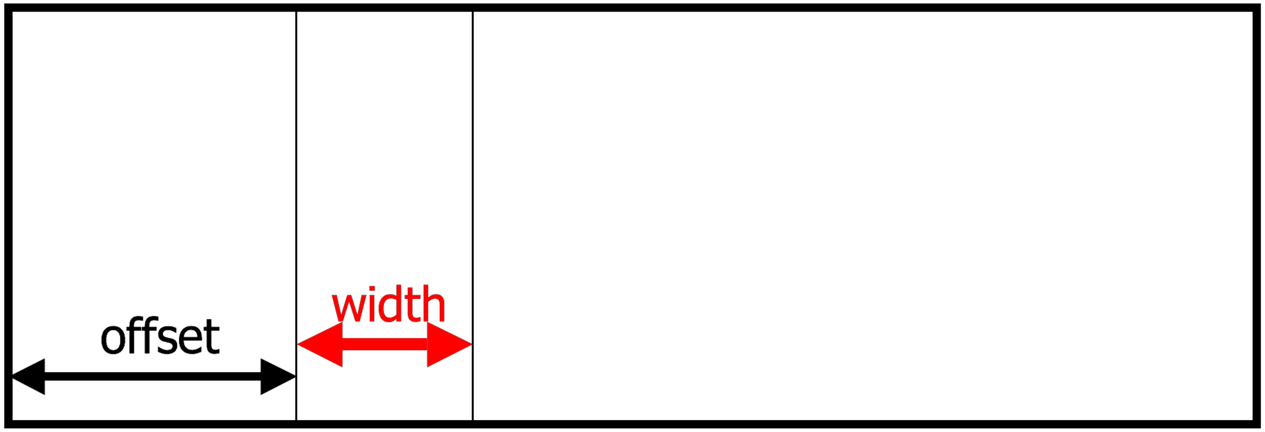
G4PVDivision - 2

```
G4PVDivision(const G4String& pName,
    G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,
    const EAxis pAxis,
    const G4double width,   // width of daughter volume is given
    const G4double offset);
```

- The number of daughter volumes is calculated as

  `int( ( (size of mother) - offset ) / width )`

  - As many daughters as width and offset allow



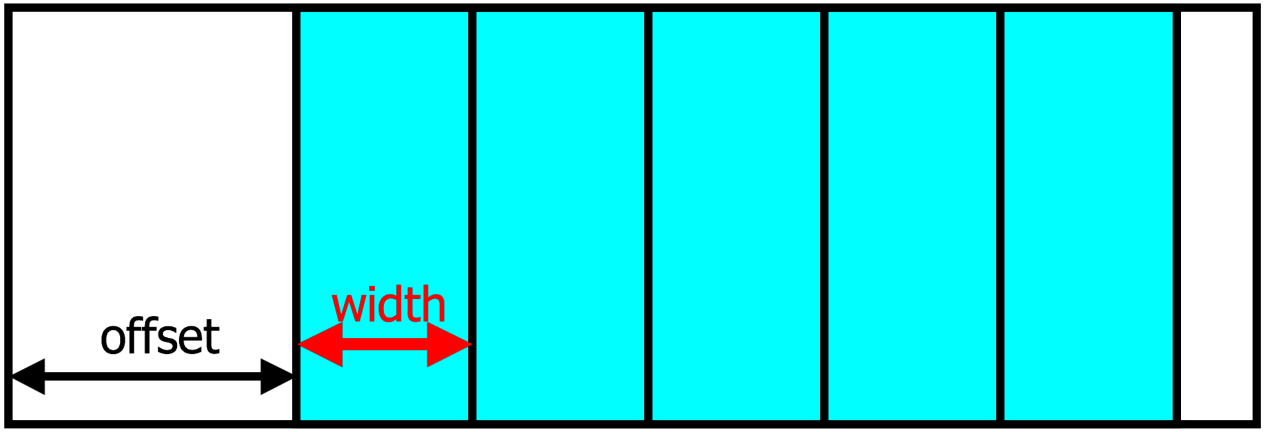
G4PVDivision - 2

```
G4PVDivision(const G4String& pName,
     G4LogicalVolume* pDaughterLogical,
     G4LogicalVolume* pMotherLogical,
     const EAxis pAxis,
     const G4double width,   // width of daughter volume is given
     const G4double offset);
```

- The number of daughter volumes is calculated as

  ```
  int( ( (size of mother) - offset ) / width )
  ```

  - As many daughters as width and offset allow



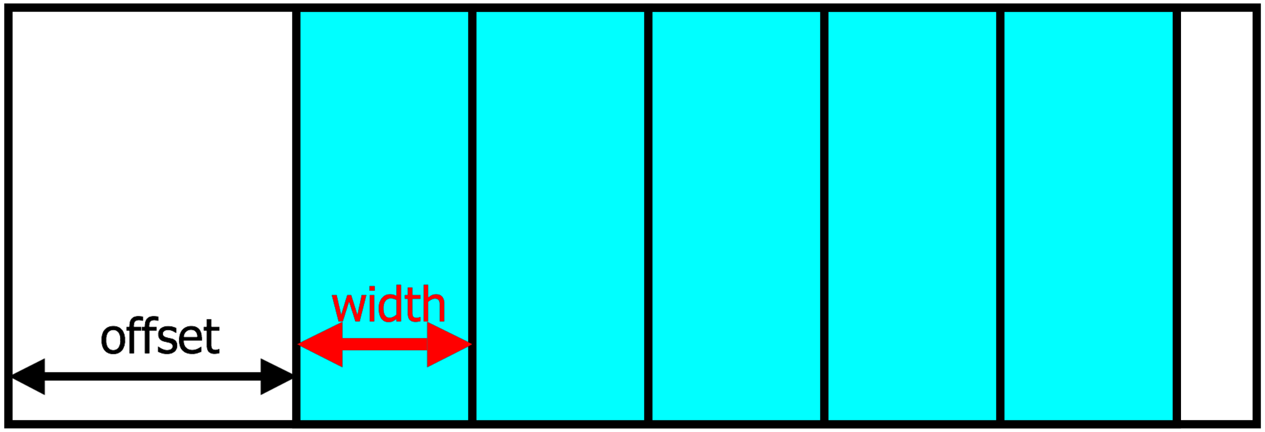
G4PVDivision - 2

```
G4PVDivision(const G4String& pName,
    G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,
    const EAxis pAxis,
    const G4double width,   // width of daughter volume is given
    const G4double offset);
```

- The number of daughter volumes is calculated as

  `int( ( (size of mother) - offset ) / width )`

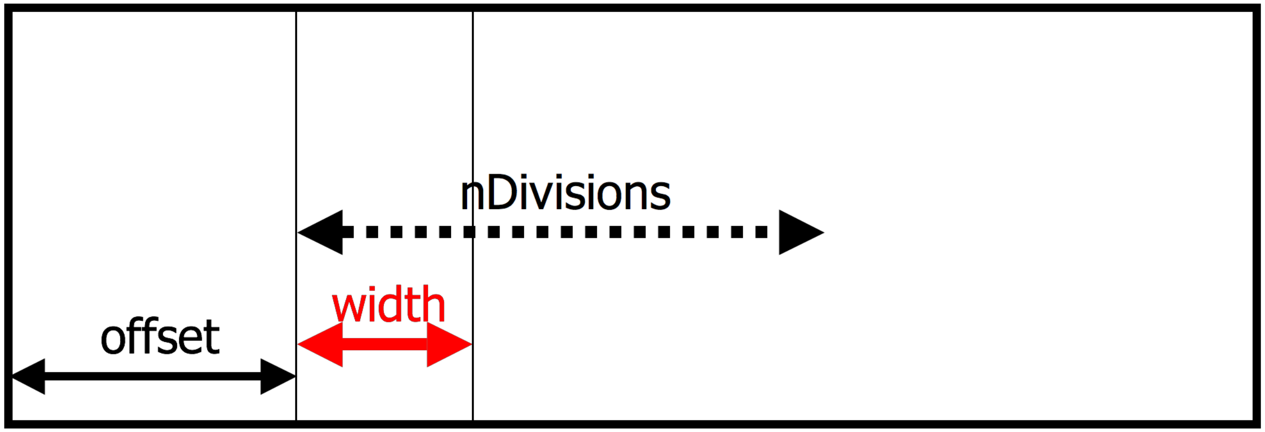
  - As many daughters as width and offset allow



G4PVDivision - 3

```
G4PVDivision(const G4String& pName,
      G4LogicalVolume* pDaughterLogical,
      G4LogicalVolume* pMotherLogical,
      const EAxis pAxis,
      const G4int nDivisions,
      const G4double width,     // both number of division and width are given
      const G4double offset);
```

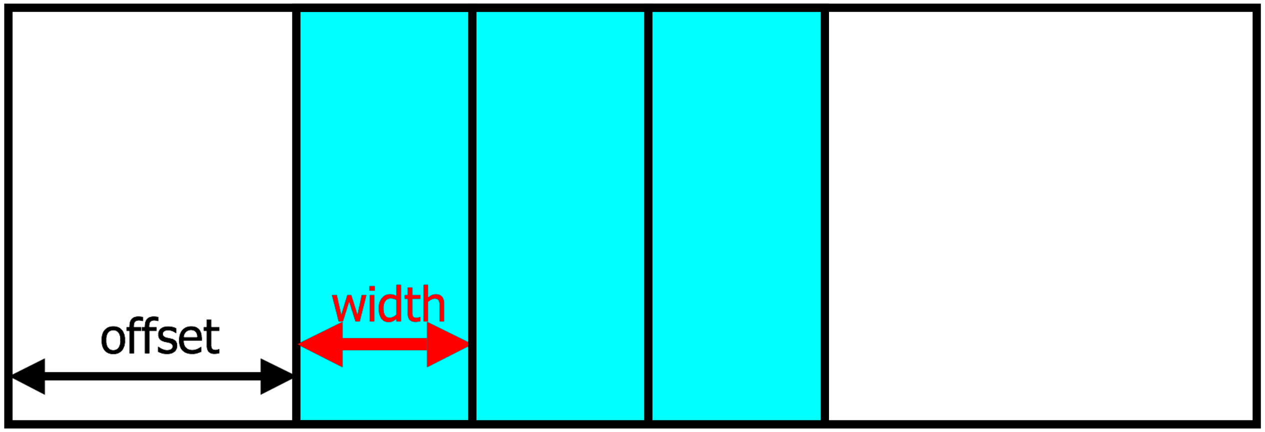
- *nDivisions* daughters of *width* thickness



G4PVDivision - 3

```
G4PVDivision(const G4String& pName,
    G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,
    const EAxis pAxis,
    const G4int nDivisions,
    const G4double width,    // both number of division and width are given
    const G4double offset);
```

- *nDivisions* daughters of *width* thickness



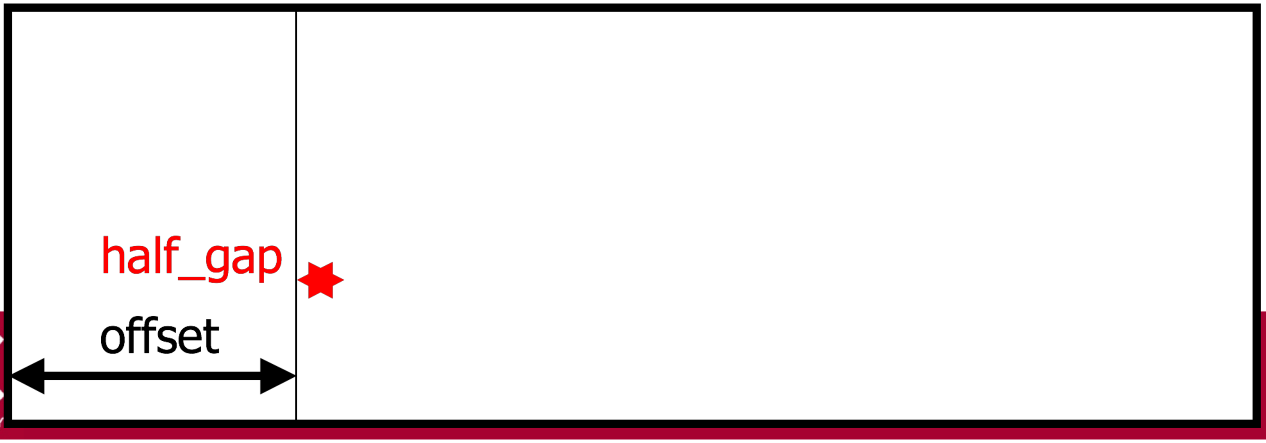
G4PVDivision

- G4PVDivision currently supports following shapes / axes.
  - G4Box : kXAxis, kYAxis, kZAxis
  - G4Tubs : kRho, kPhi, kZAxis
  - G4Cons : kRho, kPhi, kZAxis
  - G4Trd : kXAxis, kYAxis, kZAxis
  - G4Para : kXAxis, kYAxis, kZAxis
  - G4Polycone : kRho, kPhi, kZAxis
    - kZAxis - the number of divisions has to be the same as solid sections, (i.e. numZPlanes-1), the width will not be taken into account.
  - G4Polyhedra : kRho, kPhi, kZAxis
    - kPhi - the number of divisions has to be the same as solid sides, (i.e. numSides), the width will not be taken into account.
    - kZAxis - the number of divisions has to be the same as solid sections, (i.e. numZPlanes-1), the width will not be taken into account.
- In the case of division along kRho of G4Cons, G4Polycone, G4Polyhedra, if width is provided, it is taken as the width at the -Z radius; the width at other radii will be scaled to this one.

G4ReplicatedSlice

- New extension of G4Division introduced with version 9.4.
- It allows gaps in between divided volumes.

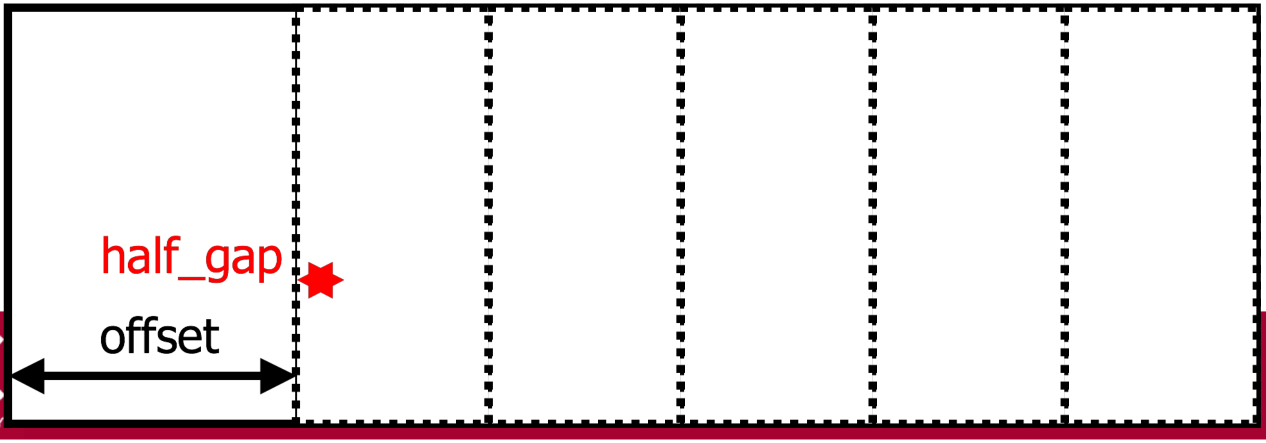
```
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,  const EAxis pAxis,
    const G4int nDivisions, const G4double half_gap, const G4double offset);
G4PVDivision(const G4String& pName,  G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4double width, const G4double half_gap,  const G4double offset);
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4int nDivisions, const G4double width,
    const G4double half_gap, const G4double offset);
```



G4ReplicatedSlice

- New extension of G4Division introduced with version 9.4.
- It allows gaps in between divided volumes.

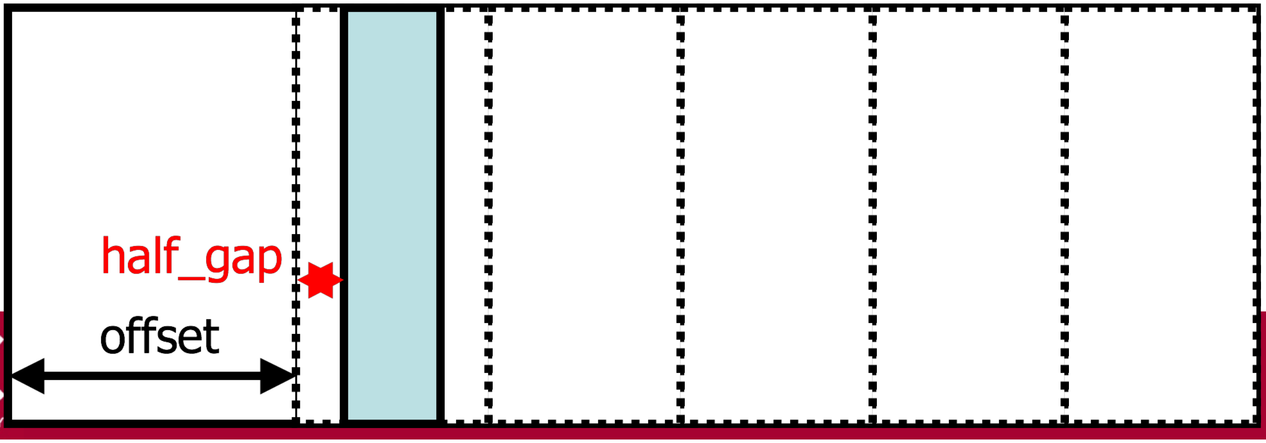
```
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,  const EAxis pAxis,
    const G4int nDivisions, const G4double half_gap, const G4double offset);
G4PVDivision(const G4String& pName,  G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4double width, const G4double half_gap,  const G4double offset);
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4int nDivisions, const G4double width,
    const G4double half_gap, const G4double offset);
```



G4ReplicatedSlice

- New extension of G4Division introduced with version 9.4.
- It allows gaps in between divided volumes.

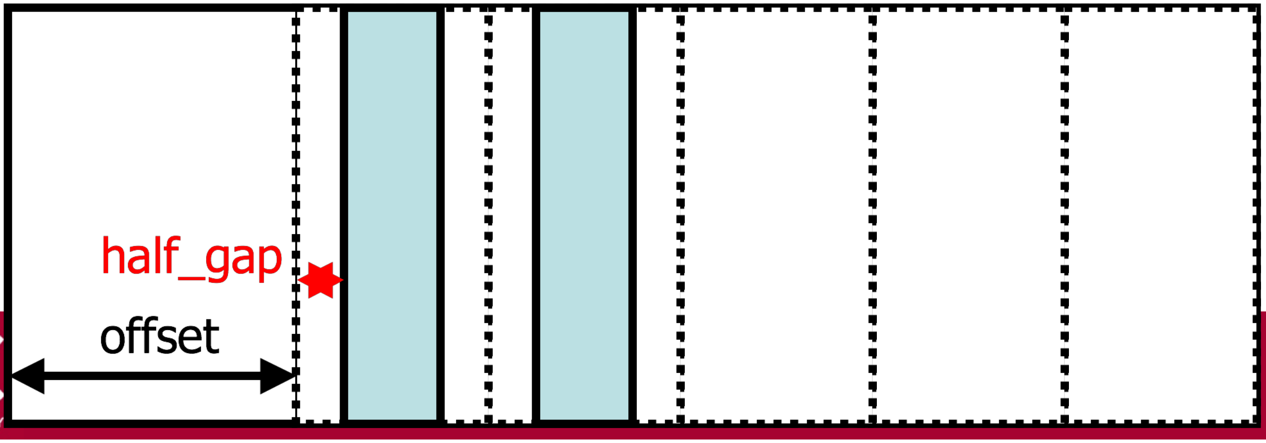
```
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,  const EAxis pAxis,
    const G4int nDivisions, const G4double half_gap, const G4double offset);
G4PVDivision(const G4String& pName,  G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4double width, const G4double half_gap,  const G4double offset);
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4int nDivisions, const G4double width,
    const G4double half_gap, const G4double offset);
```



G4ReplicatedSlice

- New extension of G4Division introduced with version 9.4.
- It allows gaps in between divided volumes.

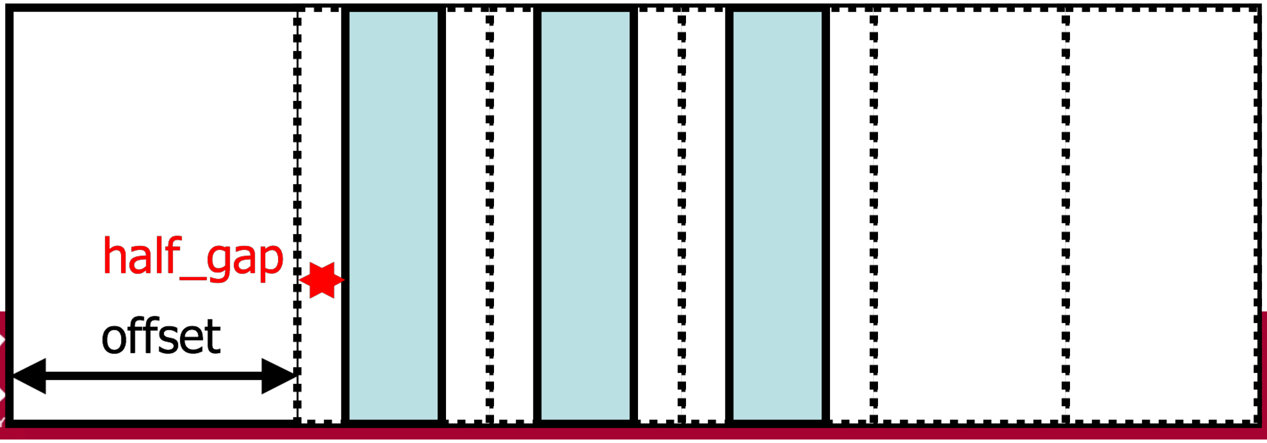
```
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,  const EAxis pAxis,
    const G4int nDivisions, const G4double half_gap, const G4double offset);
G4PVDivision(const G4String& pName,  G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4double width, const G4double half_gap,  const G4double offset);
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4int nDivisions, const G4double width,
    const G4double half_gap, const G4double offset);
```



G4ReplicatedSlice

- New extension of G4Division introduced with version 9.4.
- It allows gaps in between divided volumes.

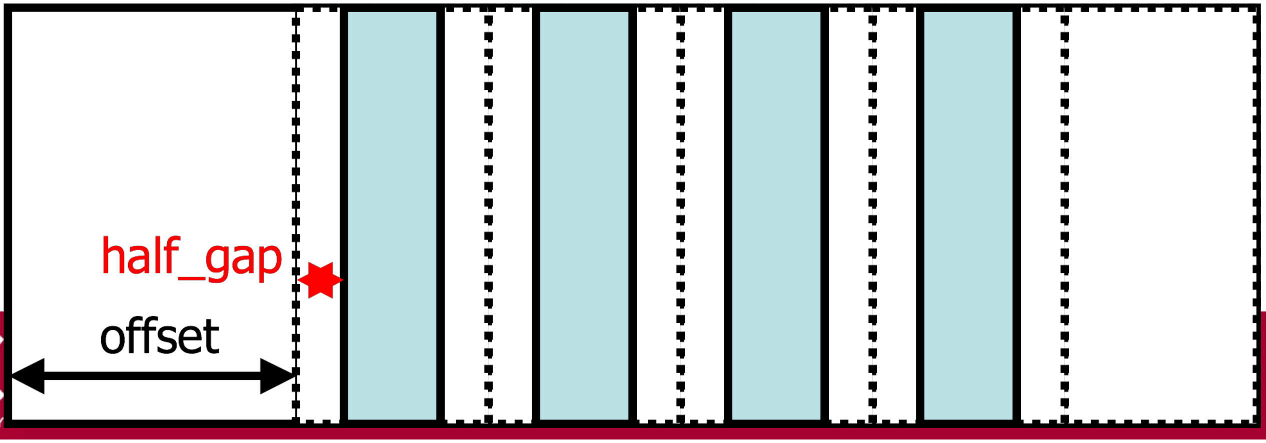
```
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,  const EAxis pAxis,
    const G4int nDivisions, const G4double half_gap, const G4double offset);
G4PVDivision(const G4String& pName,  G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4double width, const G4double half_gap,  const G4double offset);
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4int nDivisions, const G4double width,
    const G4double half_gap, const G4double offset);
```



G4ReplicatedSlice

- New extension of G4Division introduced with version 9.4.
- It allows gaps in between divided volumes.

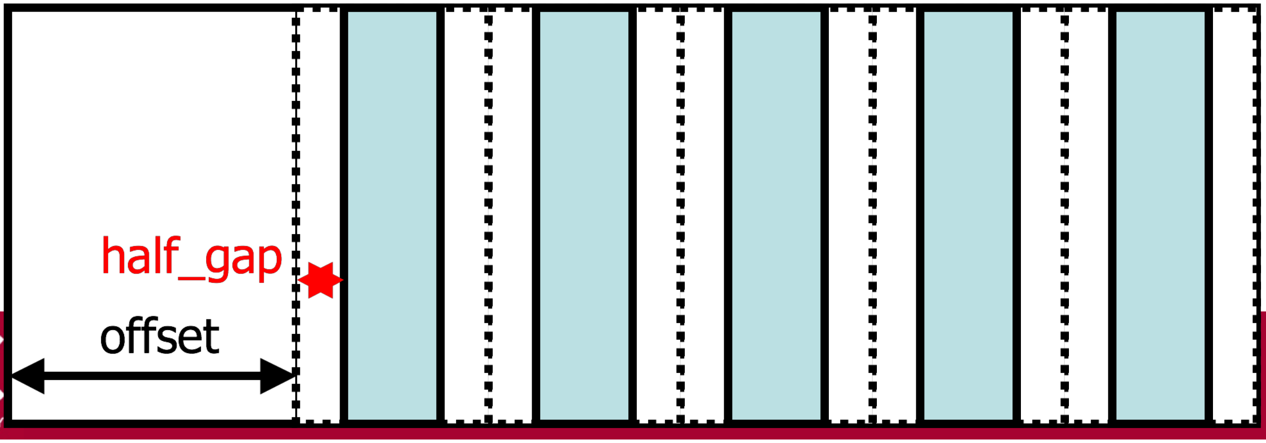
```
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,  const EAxis pAxis,
    const G4int nDivisions, const G4double half_gap, const G4double offset);
G4PVDivision(const G4String& pName,  G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4double width, const G4double half_gap,  const G4double offset);
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4int nDivisions, const G4double width,
    const G4double half_gap, const G4double offset);
```



G4ReplicatedSlice

- New extension of G4Division introduced with version 9.4.
- It allows gaps in between divided volumes.

```
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical,  const EAxis pAxis,
    const G4int nDivisions, const G4double half_gap, const G4double offset);
G4PVDivision(const G4String& pName,  G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4double width, const G4double half_gap,  const G4double offset);
G4PVDivision(const G4String& pName, G4LogicalVolume* pDaughterLogical,
    G4LogicalVolume* pMotherLogical, const EAxis pAxis,
    const G4int nDivisions, const G4double width,
    const G4double half_gap, const G4double offset);
```



Touchable

Geant 4

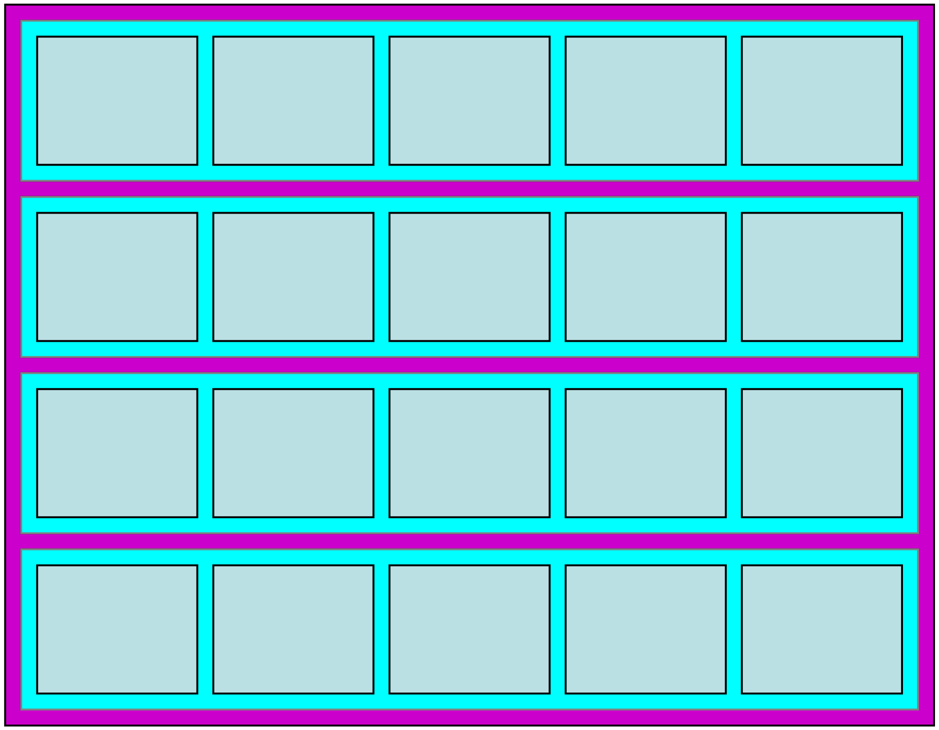
Step point and touchable

- As mentioned already, G4Step has two G4StepPoint objects as its starting and ending points. All the geometrical information of the particular step should be taken from "PreStepPoint".
  - Geometrical information associated with G4Track is identical to "PostStepPoint".
- Each G4StepPoint object has
  - Position in world coordinate system
  - Global and local time
  - Material
  - G4TouchableHistory for geometrical information
- G4TouchableHistory object is a vector of information for each geometrical hierarchy.
  - copy number
  - transformation / rotation to its mother
- Since release 4.0, *handles* (or *smart-pointers*) to touchables are intrinsically used. Touchables are reference counted.

Copy number

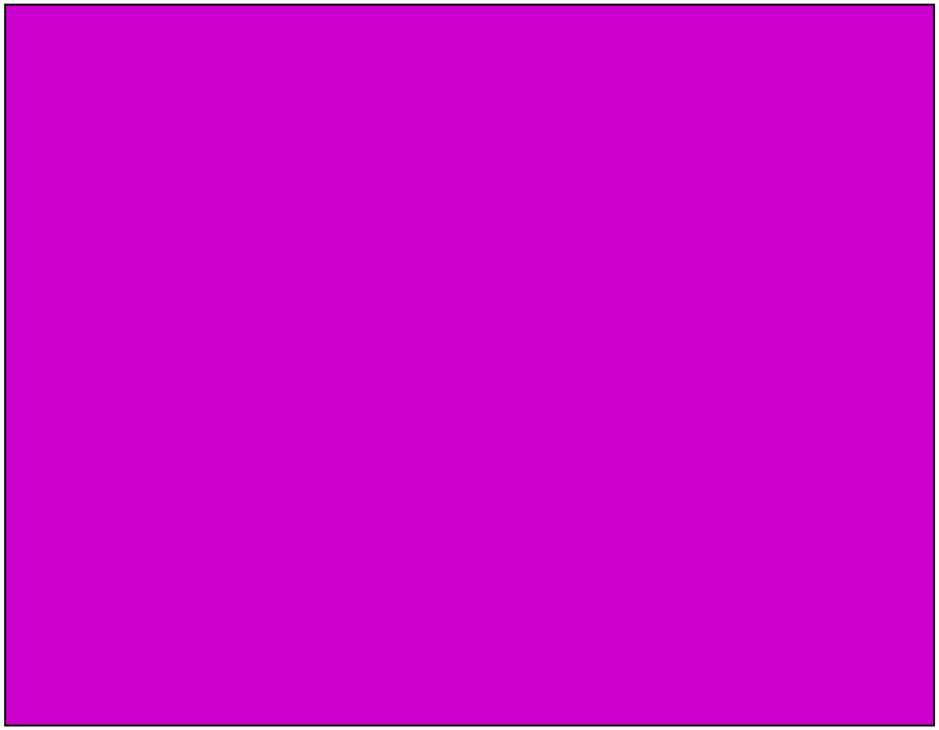
Copy number

- Suppose a calorimeter is made of 4x5 cells.



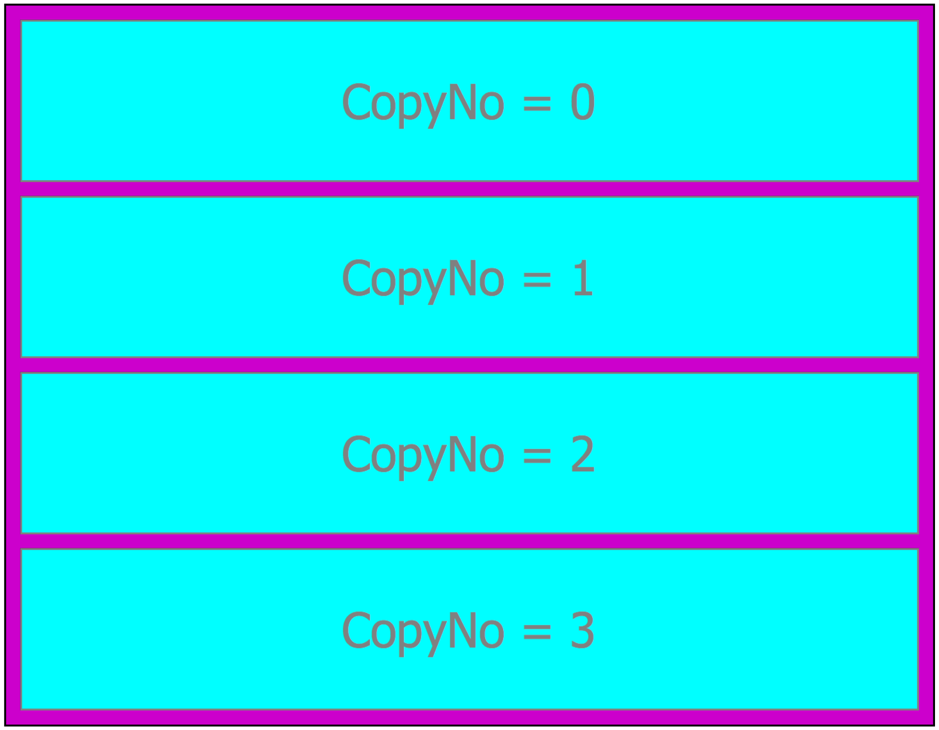
Copy number

- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.



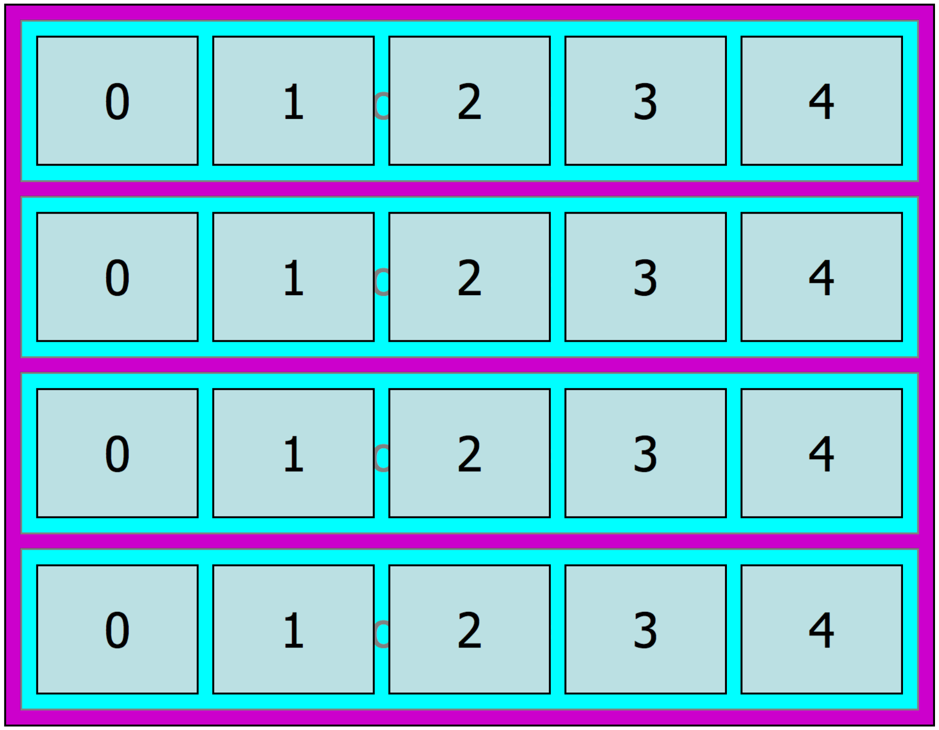
Copy number

- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.



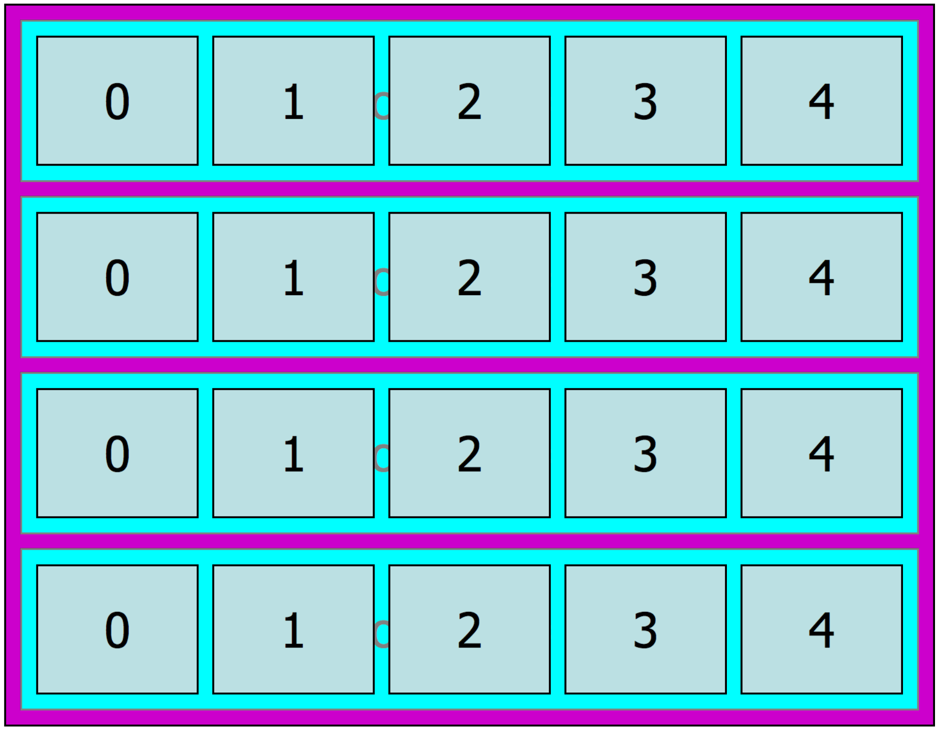
Copy number

- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.



Copy number

- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.
- In reality, there is only one physical volume object for each level. Its position is parameterized by its copy number.



0 1 2 3 4

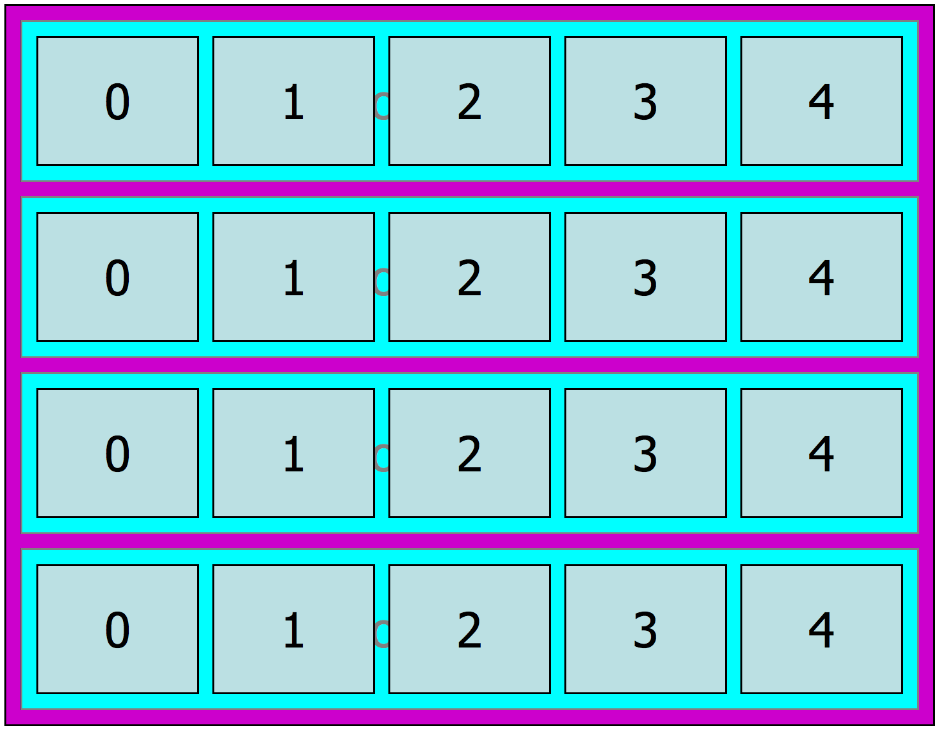
0 1 2 3 4

0 1 2 3 4

0 1 2 3 4

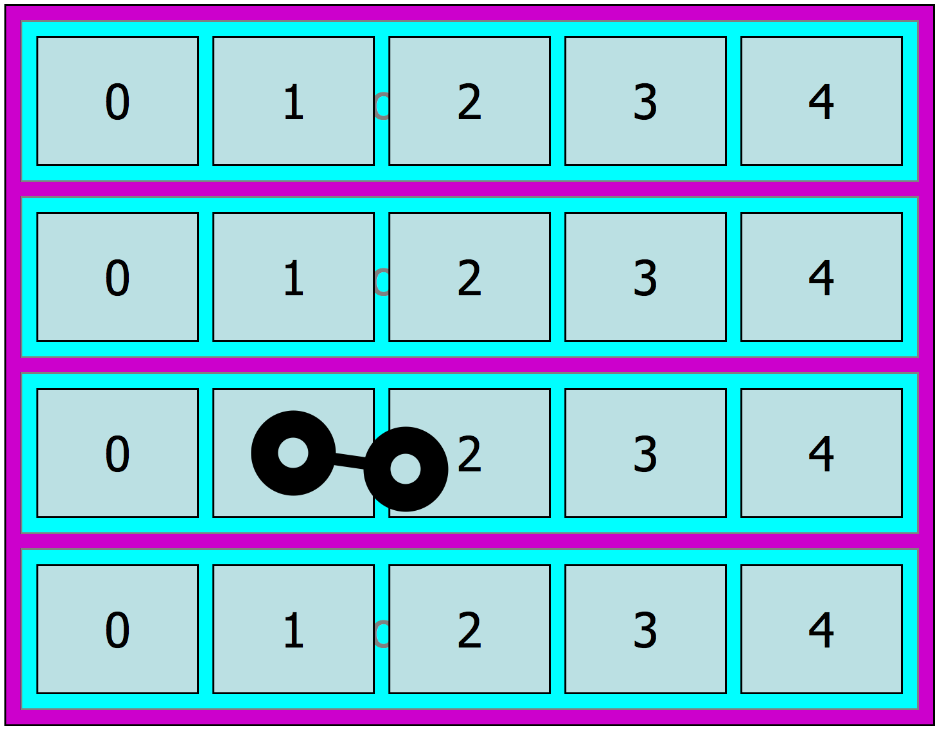
Copy number

- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.
- In reality, there is only one physical volume object for each level. Its position is parameterized by its copy number.
- To get the copy number of each level, suppose what happens if a step belongs to two cells.



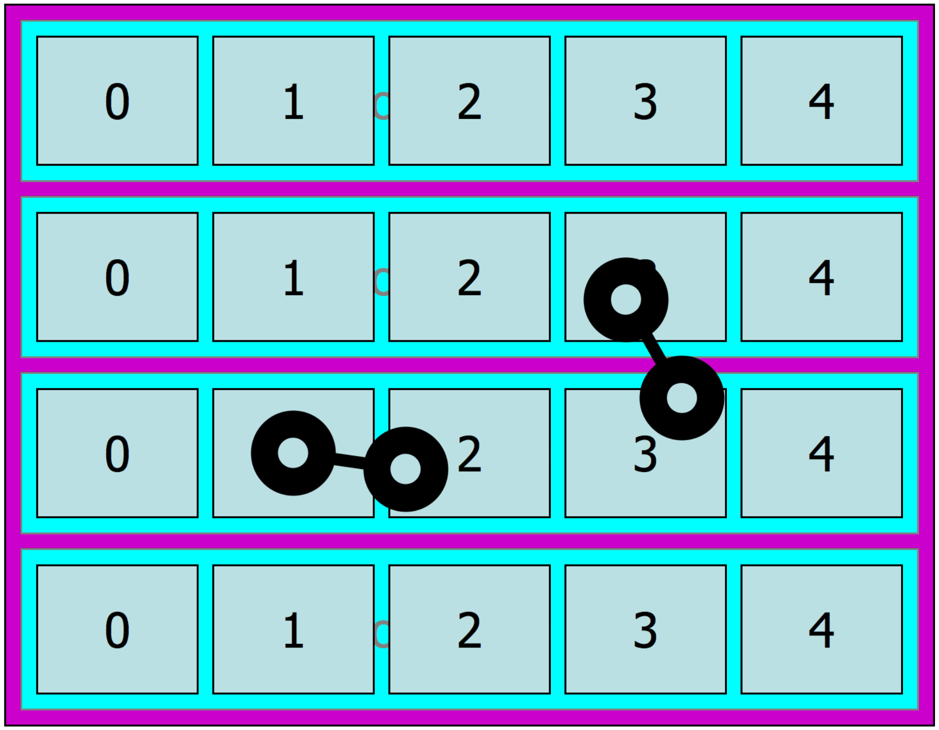
Copy number

- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.
- In reality, there is only one physical volume object for each level. Its position is parameterized by its copy number.
- To get the copy number of each level, suppose what happens if a step belongs to two cells.



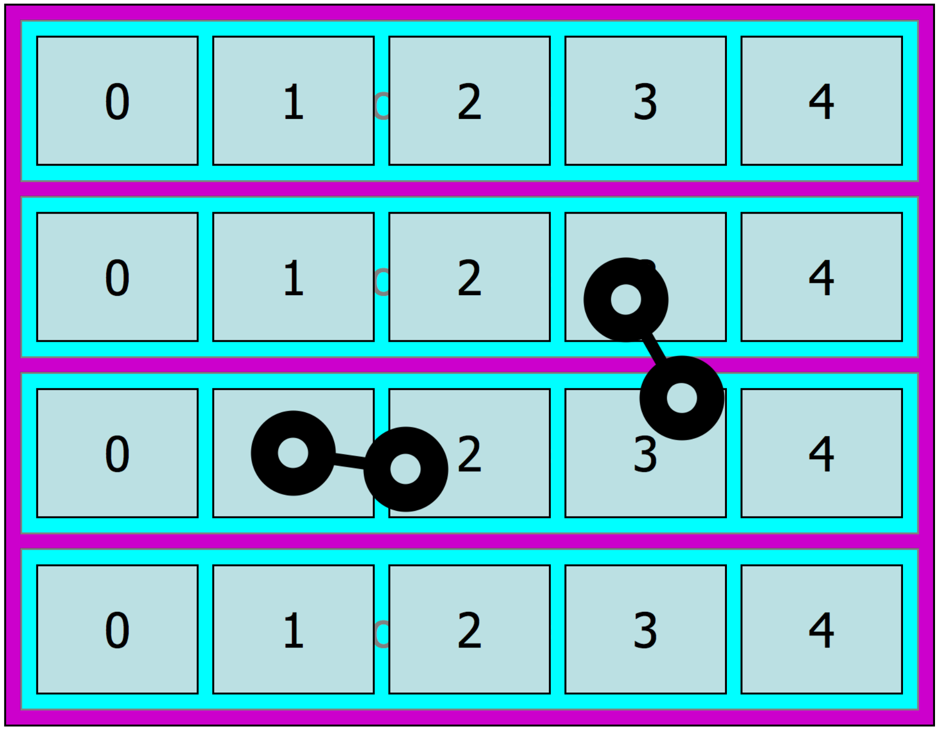
Copy number

- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.
- In reality, there is only one physical volume object for each level. Its position is parameterized by its copy number.
- To get the copy number of each level, suppose what happens if a step belongs to two cells.



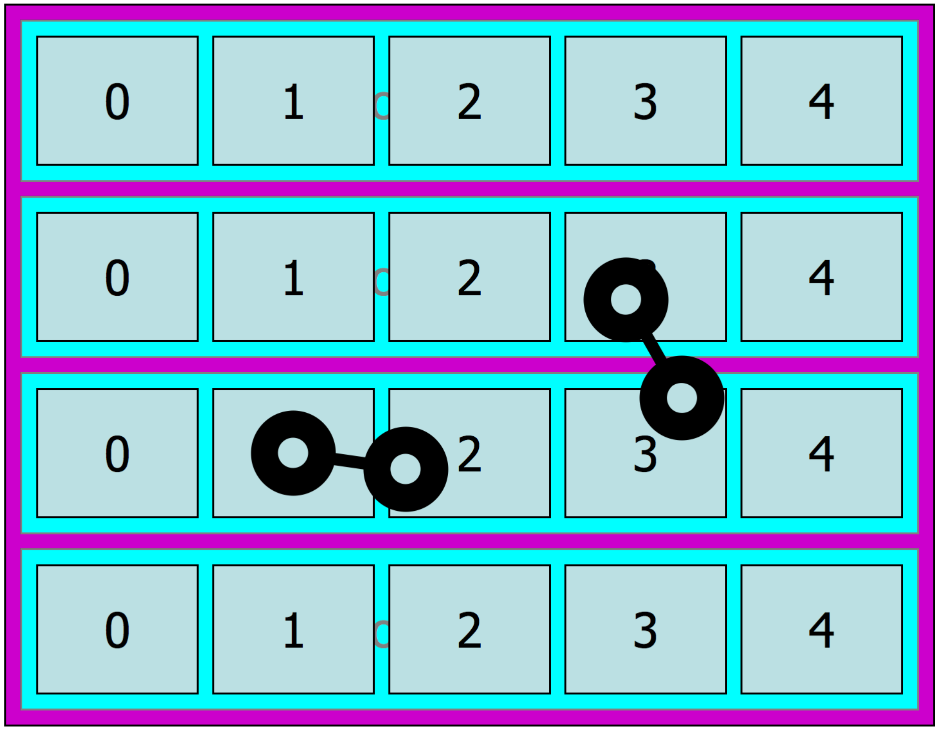
Copy number

- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.
- In reality, there is only one physical volume object for each level. Its position is parameterized by its copy number.
- To get the copy number of each level, suppose what happens if a step belongs to two cells.



Copy number

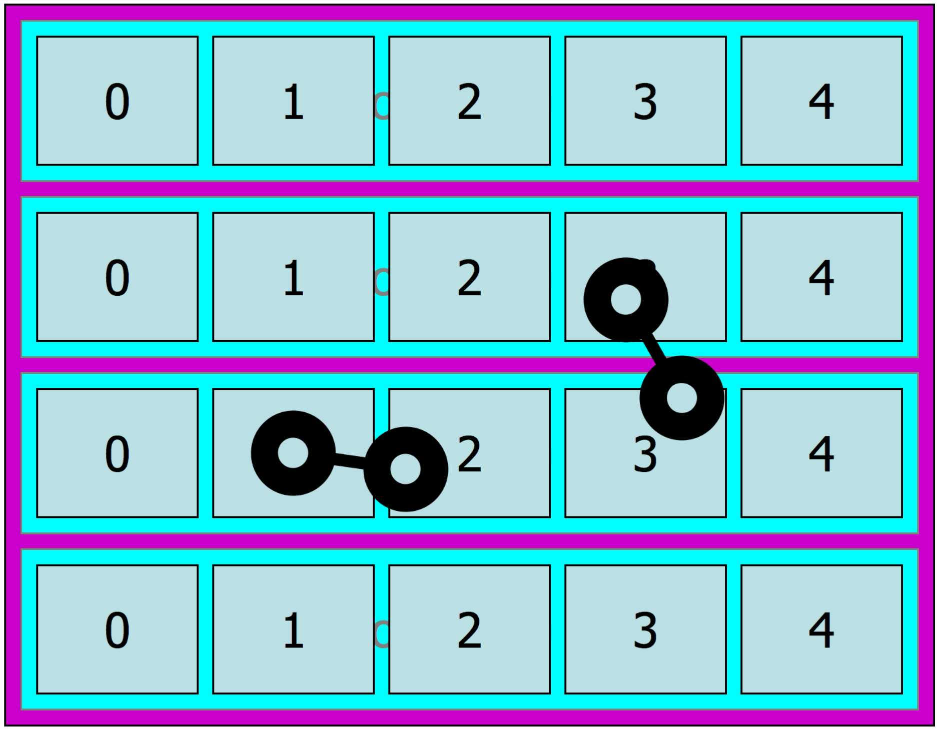
- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.
- In reality, there is only one physical volume object for each level. Its position is parameterized by its copy number.
- To get the copy number of each level, suppose what happens if a step belongs to two cells.



  - Remember geometrical information in G4Track is identical to "PostStepPoint".

Copy number

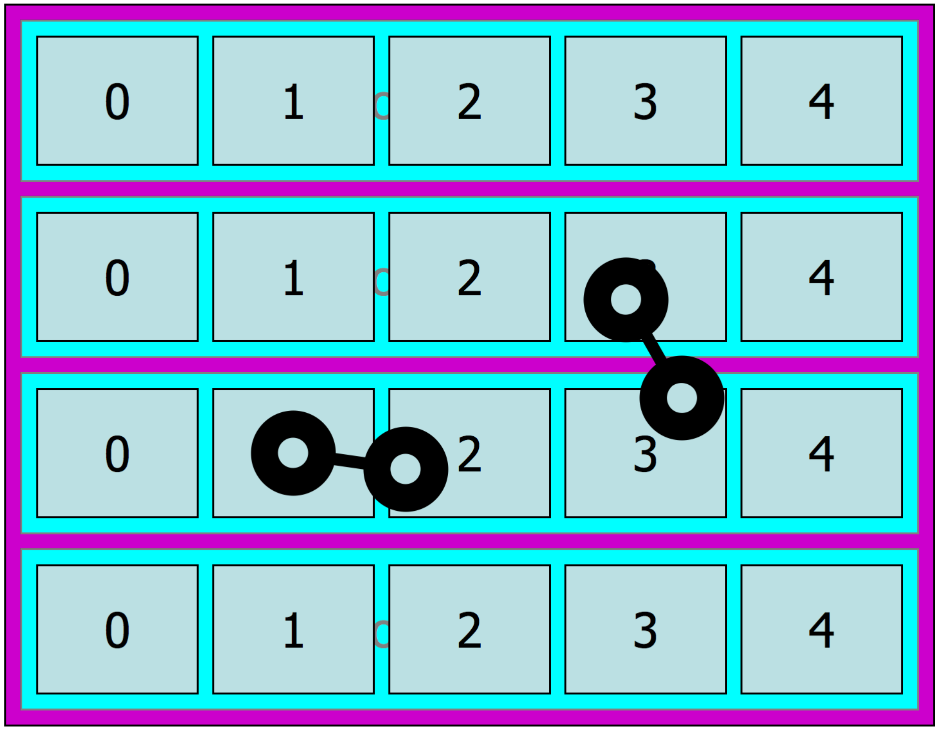
- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.
- In reality, there is only one physical volume object for each level. Its position is parameterized by its copy number.
- To get the copy number of each level, suppose what happens if a step belongs to two cells.



  - Remember geometrical information in G4Track is identical to "PostStepPoint".
  - You cannot get the correct copy number for "PreStepPoint" if you directly access to the physical volume.

Copy number

- Suppose a calorimeter is made of 4x5 cells.
  - and it is implemented by two levels of replica.
- In reality, there is only one physical volume object for each level. Its position is parameterized by its copy number.
- To get the copy number of each level, suppose what happens if a step belongs to two cells.



  - Remember geometrical information in G4Track is identical to "PostStepPoint".
  - You cannot get the correct copy number for "PreStepPoint" if you directly access to the physical volume.
- Use touchable to get the proper copy number, transform matrix, etc.

Touchable

- G4TouchableHistory has information of geometrical hierarchy of the point.

```
G4Step* aStep;
G4StepPoint* preStepPoint = aStep->GetPreStepPoint();
G4TouchableHistory* theTouchable =
    (G4TouchableHistory*)(preStepPoint->GetTouchable());
G4int copyNo = theTouchable->GetVolume()->GetCopyNo();
G4int motherCopyNo
            = theTouchable->GetVolume(1)->GetCopyNo();
G4int grandMotherCopyNo
            = theTouchable->GetVolume(2)->GetCopyNo();
G4ThreeVector worldPos = preStepPoint->GetPosition();
G4ThreeVector localPos = theTouchable->GetHistory()
    ->GetTopTransform().TransformPoint(worldPos);
```